Summary of Direct Testimony of

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United States Fish and Wildlife Service

Department of Interior

To be presented during the Water Right/Water Quality Hearing scheduled for September 21, 22, 23, 1987.

Part 1

Part 1 of my testimony will be a summary of results of salmon studies conducted by the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

My testimony will describe the water quality and flow conditions necessary for the protection of chinook salmon in the Estuary. These conditions will be compared to the water quality standards in the 1978 Delta Plan.

The evidence presented will demonstrate how flow, temperature and water diversions affect juvenile outmigrant survival in the Delta and thus influence adult salmon production. Additional information on the estuarine ecology of salmon will be provided to include juvenile rearing, juvenile and adult migration, plus a general overview of the status of Central Valley stocks and salmon management strategies.

I will refer to U.S. Fish and Wildlife Service Exhibit Number 31 provided to you for this testimony.

Part 2

In Part 2 of my testimony I will present the specific comments of the U.S. Fish and Wildlife Service on the Interagency Ecological Study Program's salmon report.

HEARING PROCESS
SAN FRANCISCO BAY / SACRAMENTO - SAN JOAQUIN DELTA ESTUARY

INDEX OF EXHIBITS

HEARING PHASE I

PARTICIPANT Alison D. Ling, Attorney for U.S. Dept. of the Interior PAGE 1 OF 1

EXHIBIT NUMBER	DESCRIPTION / PURPOSE OF USE (For referenced exhibits, also include the title and portions relied upon)	REFERENCED YES / NO	COST	
30	Qualifications Statement - Dr. Martin A. Kjelson	No	$ .13	✓
31	Report - Needs of Chinook Salmon in the Sacramento-San Joaquin Estuary	No	$24.96	✓
32	Qualifications Statement - Patricia L. Brandes	No	$ .13	✓
33	Qualifications Statement - Dr. John D. McIntyre	No	$ .13	✓
34	Qualifications Statement - Dr. Reginald R. Risenbichler	No	$ .13	✓
27	Qualifications Statement - David A. Vogel	No	$ .13	
	(USFWS Exhibit No. 27 originally provided under the Hearing topic "Uses Upstream of the Estuary")		25.61	

SEND REQUEST FOR COPIES OF EXHIBITS AND REMITTANCE TO:

James J. McKevitt
Field Supervisor
Division of Ecological Services
U.S. Fish and Wildlife Service
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Sacramento, California 95825

Make remittance payable to:
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ATTACHMENT D

SUMMARY OF QUALIFICATIONS

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Member of the American Fisheries Society, Pacific Fishery Biologists, Pacific Estuarine Research Society.

USFWS Exhibit No. 30

Exhibit 31, entered by the U.S. Fish and Wildlife Service for the State Water Resources Control Board 1987 Water Quality/Water Rights Proceeding on the San Francisco Bay/Sacramento-San Joaquin Delta.

The Needs of Chinook Salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin Estuary

PREFACE

Interagency staff representing the U.S. Fish and Wildlife Service had lead responsibility in preparing this report. Drafts have been reviewed by members of the fisheries/water quality committee of the Interagency Ecological Studies Program for the Sacramento-San Joaquin estuary and by other salmon experts. The Interagency staffs and their consultants have also met on several occasions to discuss the interpretation of specific data and general approach to the report itself.

The report reflects the fisheries/water quality committee members' agreement on most points. Committee members will provide direct testimony on areas of disagreement.

Agency management was not part of the review process and may differ on how study results can be used in managing salmon resources.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Section 1

SYNOPSIS OF SALMON MANAGEMENT NEEDS IN THE ESTUARY

Introduction

The main objective of this report is to describe the conditions that provide for the protection of chinook salmon in the Sacramento-San Joaquin Estuary. This information should help the Board in setting standards that will provide reasonable protection of beneficial uses in the Estuary. Chinook salmon are a beneficial use that support an intense commercial and recreational fishery whose annual catch averages about 400,000 fish. This represents a significant economic and recreational resource for California.

Chinook use the Bay and Delta habitat as a salmon nursery and for juvenile and adult migrations to and from the ocean and their freshwater habitat. Available evidence indicates that existing water quality standards in the 1978 Delta Plan are inadequate for salmon protection and will result in the survival of juvenile chinook migrating through either the Sacramento or San Joaquin Delta being substantially less than historical survival rates.

Stock Status and the Delta Problem for Salmon

Four runs of chinook salmon (fall, late-fall, winter and spring) are produced in the Central Valley. Fall-run are the focus of this report and comprise over 90% of all spawners. The Sacramento Basin accounts for over 80% of the production. Naturally produced chinook stock in Valley streams have declined by over 50% since the early 1950's. These losses are attributable to habitat reduction in both upstream and estuarine areas.

The evidence presented in this report will demonstrate that habitat alterations in the Delta limit salmon production primarily through reduced survival during the outmigrant (smolt) stage. These lower survivals are associated with decreases in the magnitude of flow through the estuary, increases in water temperatures and water project diversions in the Delta.

Smolt mortality in the Estuary will impact resulting adult salmon population levels. However, other factors that influence stocks and their measurement in upstream and oceanic waters make that impact difficult to quantify. Nevertheless, increasing smolt survival rates through the Delta is a critical step toward restoring natural salmon production in the Central Valley.

Since the early 1970's, juvenile chinook salmon produced at the Feather River, Nimbus and Mokelumne River hatcheries have been trucked downstream and released in the Sacramento River at Rio Vista or adjacent to Carquinez Strait. Since these fish are not exposed to Delta hazards their contribution to the ocean fishery and to subsequent spawning runs is often high. Chinook salmon from Coleman and Merced River hatcheries are released in upriver areas near the hatcheries to prevent the straying of returning spawners which occurs when juvenile salmon from upriver are released in the Estuary. The release of hatchery fish in the lower estuary has enabled a relatively intense ocean fishery to remain stable concurrent with reduced natural salmon populations. The success of the hatchery program, however, increases the risk of overharvesting natural stocks or of hatchery fish that must pass through the Delta.

Estuarine Salmon Ecology and Conditions for Improved Salmon Protection

Juvenile Salmon Migration and Abundance

Fall-run salmon migrate through the Estuary to the ocean from April through June with peak abundances seen in May. Salmon of the other three runs migrate between fall and early spring.

The abundance of smolts at Chipps Island is positively correlated to Sacramento River flow at Rio Vista.

Smolt migration through the Bay/Delta system takes about 10 to 15 days. Rough estimates of the annual number of fall-run smolts leaving the Delta from 1978 to 1986 ranged from about 10 to 50 million fish. These represent about 200,000 to one million adults respectively to the ocean fishery.

Smolt Survival

Sacramento River Delta

The survival of marked hatchery smolts through the Sacramento Delta between Sacramento and Suisun Bay is positively correlated to flow and negatively correlated to both temperature and the percent of the flow diverted off the Sacramento River through the Delta cross channel and Georgiana Slough at Walnut Grove.

Smolt survival increased with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above

20,000 to 30,000 cfs. This relation was based on two independent measures of survival.

Smolt survival is highest when water temperatures are below 66°F. Temperatures of 76°F or higher are lethal to salmon and stress would occur as temperatures approach that level.

Diverting smolts off the Sacramento River into the Central Delta lessens their survival. Evidence of this is 1) when about 65% of the Sacramento River was diverted to the Central Delta, tagged smolts released immediately above the Walnut Grove diversion point survived at only 50% of the rate of those released immediately below Walnut Grove, 2) when the cross channel was closed, the difference in survival for the two groups was zero at high flows, and about 25% at low flows, and 3) survival of tagged smolts released in the Central Delta was about 50% less than those released in the Sacramento River below Walnut Grove during years of low flow and similar temperatures. Hence, closing the Cross channel is of considerable benefit to salmon survival at low flows when temperatures are acceptable.

Since both temperature and diversions increase as flows decrease, it is difficult to detemine the relative contributions of these factors to changes in survival observed in the Estuary. We believe, however, that both temperature and diversions cause survival to decrease as flows decrease.

Existing flow and operational standards in the 1978 Delta plan are inadequate. Salmon flow standards at Rio Vista range from 1,000 to 5,000 cfs which would yield from zero to 2% survival based on the relationship between smolt survival and flow. Striped bass Delta outflow standards in May and June afford higher protection and would improve survival to an estimated 5% in dry years to 35% in wet years.

Water development in the Sacramento Valley has reduced inflow to the Delta during the April-June smolt migration period. These reductions combined with the present Delta diversions off the Sacramento River have been enough to reduce average smolt survival in the Sacramento Delta by at least 30% since 1940.

Potential measures to improve smolt survival through the Sacramento Delta include: increasing flows, closure or screening of the Delta cross channel, elimination of reverse flows in the lower San Joaquin and reducing Project export levels in the southern Delta.

San Joaquin Delta

Typical conditions in the San Joaquin Delta are detrimental for smolt survival. This is attributed largely to low Delta inflow from the San Joaquin River, the effect of which is accentuated by diversions typically exceeding inflow during smolt migration periods. High water temperatures (typically 70°F in May) associated with low flows also stress juvenile salmon.

Survival of tagged smolts migrating from the San Joaquin drainage through the Delta increased with increased Delta inflows. Smolt survival and resulting adult production was most favorable in wet years when flows at Vernalis during smolt migration was greater than total CVP-SWP exports. The benefit of increased river flows to returning spawner numbers reflects benefits to juvenile survival both upstream and in the Delta.

Survival of tagged smolts released in the southern Delta was higher for smolts migrating down the San Joaquin River than for those diverted to the west toward the CVP-SWP pumps via upper Old River indicating that diversion is a key factor affecting smolt survival. In two of the three years studied, survival of fish released in upper Old River, and thus exposed to the Projects' diversions, was 40% to 80% lower than those released in the San Joaquin below the upper Old River Junction. In the third year there was no difference observed.

The rate at which smolts migrated through the San Joaquin Delta about doubled as inflow at Vernalis increased from 2,000 to 7,000 cfs.

There are no existing San Joaquin River flow standards in the 1978 Delta Plan for smolt survival. Project export limits in May and June provide some protection. Fish screen operational criteria also provide some protection after the fish are diverted from the river.

Potential measures to improve smolt survival in the San Joaquin Delta include: reductions in CVP-SWP export levels, a barrier or a screen at the head of upper Old River, increased flows, and elimination of reverse flows in the lower San Joaquin River. Continued juvenile survival studies are needed in the San

Joaquin system to better enable us to evalute varied salmon protective measures.

San Francisco Bay

Available data is too sparse to draw any conclusions on the influence of Delta outflow on smolt survival in the Bay. Data from 1984 indicates survival through the Bay for large juvenile salmon was relatively high (81%) for a rather low Delta outflow index of 10,000 cfs. Ocean tag recoveries available in 1988 and 1989 reflecting smolt tag releases in the Bay in 1985 and 1986 will provide two more estimates of survival through the Bay at outflows of 10,000 cfs.

Salmon Rearing

Fall run chinook fry rear both upstream and in the Estuary with peak abundances seen in the Delta in February and March. As Delta inflow increases, fry become both more numerous and more widely distributed in the estuary.

The survival of tagged fry was greater in the upper Sacramento River than in the Delta, while that in San Francisco Bay was the lowest.

Fry released in the northern Delta appeared to survive better than those released in the Central Delta except in years of very high Delta inflow.

Chinook fry that rear in the Delta contribute some portion of Central Valley salmon production with that proportion increasing as runoff increases. That contribution is probably small relative to that upriver rearing but still significant.

Adult Migration

Chinook spawners of the four runs migrate through the Estuary at different times throughout the year. Adult migration data was gained with CDFG sonic tag studies in the mid 1960's. Findings from that work indicated that: migrations through the Estuary are aided by positive downstream flows of "homestream water" and temperatures less than 66°F.

Dissolved oxygen concentrations below 5 mg/l block upstream migration.

Section 2

INTRODUCTION

In July 1987 the State Water Resources Control Board initiated a water quality/water rights proceeding on the San Francisco Bay/Sacramento-San Joaquin Delta. The Board's objective is to review and refine as necessary the present water quality standards identified in the 1978 Water Quality Control Plan for the Delta and Suisun Marsh to insure that beneficial uses are protected. Fish and wildlife resources including chinook salmon, (Oncorhynchus tshawytscha), are a beneficial use that are dependent upon the Bay and Delta habitat for critical portions of their life history. Chinook produced in the Central Valley support an intense commercial and recreational fishery whose catch averages about 400,000 annually representing a significant economic and recreational resource for California.

Several problems have the potential to limit salmon production in the Bay/Delta system. These are primarily associated with decreases in the magnitude of inflow to the Delta and water project diversions in the Delta from the Sacramento and San Joaquin rivers. The main objective of this report is to describe basic ecological relationships and needs of chinook salmon in the Estuary and to assess if present habitat protection under the 1978 Delta Plan are meeting those needs.

The report also provides information on the status of Central Valley stocks and management activities of direct impact on the stocks (harvest regulation and hatchery production). This additional information is provided to the Board to gain a more comprehensive view of the varied and complex factors that influence the overall chinook salmon resource in California The needs of salmon in upstream habitats are provided in separate exhibits by the California Department of Fish and Game and U.S. Fish and Wildlife Service.

The majority of information presented is the result of work done through the Estuarine Salmon Element of the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. The program is represented by the California Departments of Fish and Game (CDFG) and Water Resources (DWR), the State Water Resources Control Board, and the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation and U.S. Geological Survey. Cooperative work with the San Joaquin River Salmon Program (CDFG, Region 4, Fresno) yielded salmon data from the San Joaquin Delta.

The Interagency salmon studies were initiated in 1978 with emphasis on 1) indexing fall-run juvenile chinook abundance using seine and midwater trawl surveys, and 2) estimating juvenile survival using an extensive mark-recapture program using coded wire nose tags (CWT). Salmon fry rearing and smolt outmigration were documented under varied flow and diversion rates, migration routes, and other environmental conditions to identify salmon needs in the estuary and potential limitations to survival and production. These recent studies have yielded considerable new knowledge of estuarine fall-run juvenile salmon life history in the Estuary since the establishment of the 1978 Delta Water Quality Plan which relied on minimal knowledge to establish salmon protective standards. Additional information was gained from the scientific literature and from cooperative efforts with other salmon programs under the direction of U.S. Fish and Wildlife Service and the Department of Fish and Game.

Life History

Chinook salmon also called king salmon, spawn in fresh water but spend most of their adult lives in the ocean (Figure 2-1). They are the largest of five species of salmon native to the Pacific coast of North America. Chinook salmon and steelhead rainbow trout, (*Salmo gairdneri*) are the principal salmonids using the Sacramento-San Joaquin Estuary. There are four distinct salmon runs in the Sacramento system (Figure 2-2) that are named for the season of their upstream migration: spring, fall, late fall, and winter. Today, fall run are the principal run found in the San Joaquin drainage. About 80% of the Central Valley chinook of all four runs are produced in the Sacramento River basin. Typically, over 90% of all Central Valley spawners are fall run fish.

Spawning occurs where gravel size, porosity and water velocity enables the female to build a spawning redd, and deposit eggs to be fertilized and covered. Successful incubation of the eggs (50 to 60 days to hatching) requires sufficient flows to remove waste products and silt, yet low enough to prevent eggs

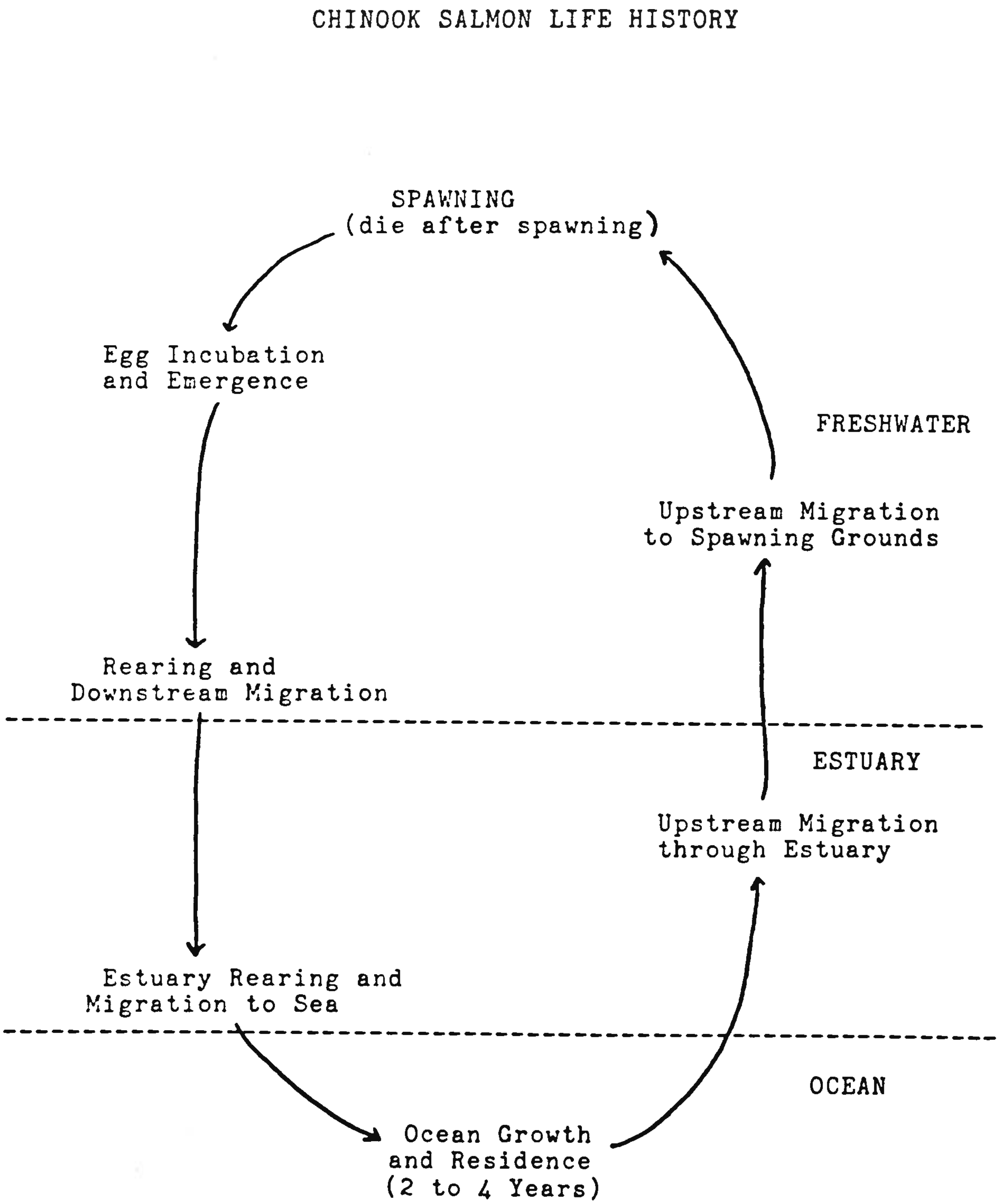

Figure 2-1: Chinook salmon life history diagram.

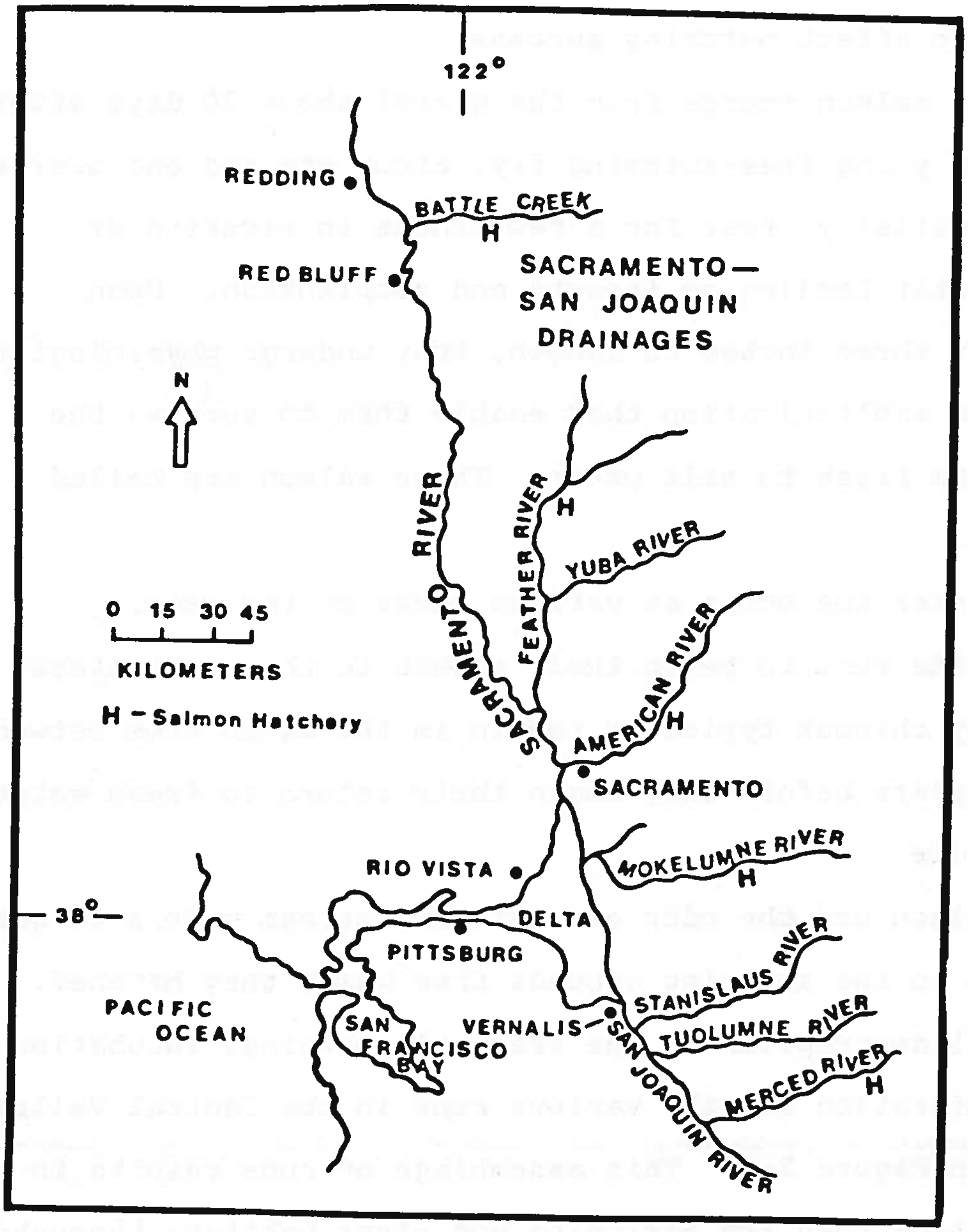

Figure 2-2. Major chinook salmon spawning streams in the Sacramento-San Joaquin drainages of California.

from being washed downstream. Temperature and dissolved oxygen conditions also affect hatching success.

The young salmon emerge from the gravel about 30 days after hatching. The young free-swimming fry, about one and one quarter inches long initially, rear for a few months in riverine or estuarine habitat feeding on insects and zooplankton. Upon reaching about three inches in length, they undergo physiological changes termed smoltification that enable them to survive the transition from fresh to salt water. These salmon are called smolts.

Smolts enter the ocean at various times of the year, depending on the run, to begin their growth to the adult stage. Central Valley chinook typically remain in the ocean from between two and four years before they begin their return to fresh water to spawn and die.

Adult salmon use the odor of their homestream waters to guide them upstream to the spawning grounds from which they hatched.

A general description of the seasonal spawning, incubation, rearing and migration for the various runs in the Central Valley is provided in Figure 2-3. This assemblage of runs results in salmon inhabiting both the Bay/Delta and river habitats throughout the year.

Present Delta Salmon Standards

The 1978 Plan provides flow standards for salmon migration in the Sacramento River at Rio Vista that range from 1,000 to 5,000

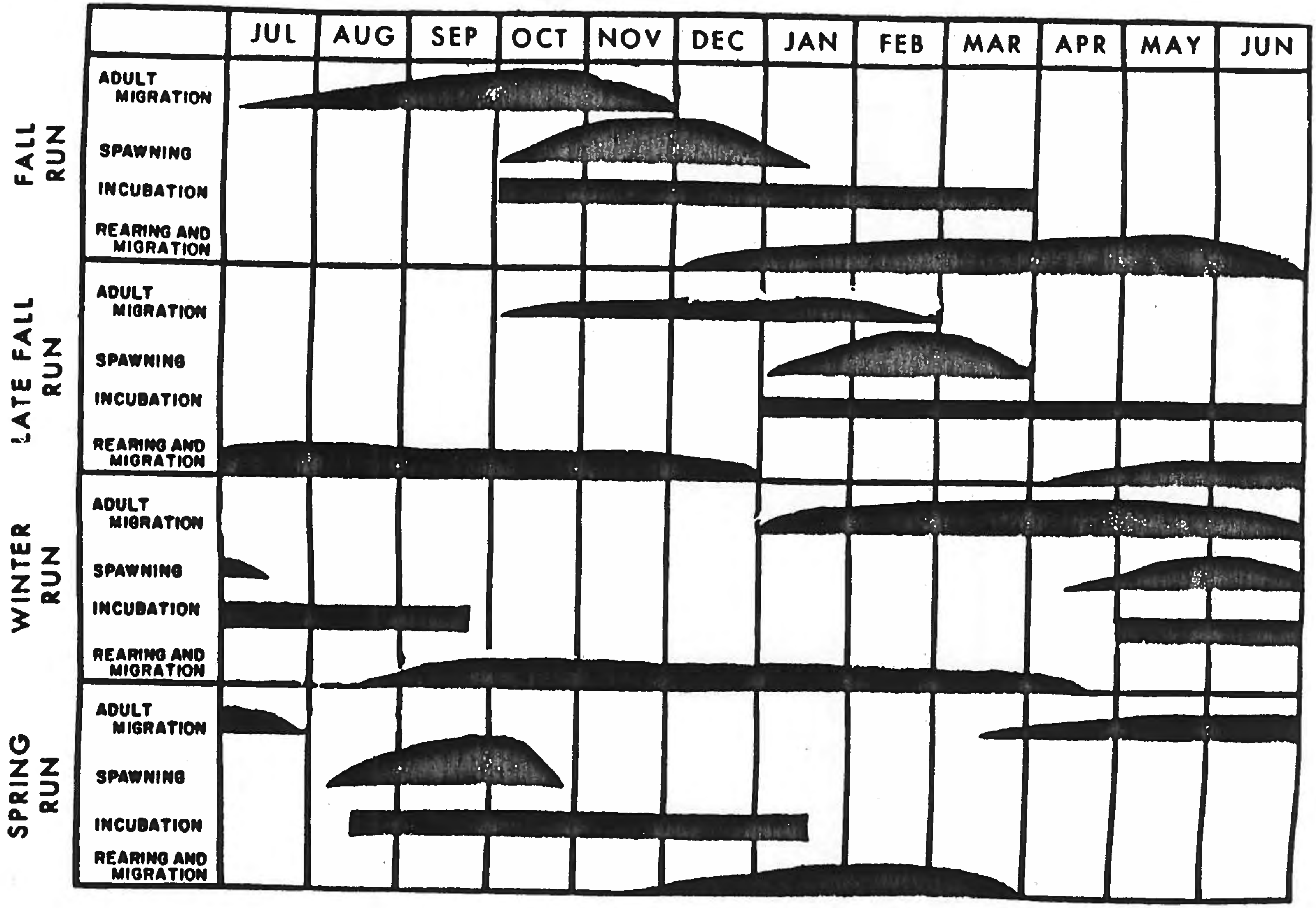

Figure 2-3. Life history characteristics of four runs of chinook salmon in the Central Valley.

cfs and vary by month and water year type. Operational criteria for the protection of salmon migration in the 1978 Plan requires closure of the Delta Cross Channel between January 1 and April 15 when Delta outflow (DOF) exceeds 12,000 cfs. When the Delta Cross Channel at Walnut Grove is closed, it lessens water diversion and movement of young salmon into the Central Delta. Fish screen operational criteria at the Central Valley and State Water Project fish facilities in the south Delta also are part of the 1978 Delta Plan. Protective standards for striped bass under the Plan yield further protection for salmon.

<u>Section 3</u>

SMOLT MIGRATION AND ABUNDANCE

Migration Period

Smolt (~70 to 100 mm) and yearling size (>100 to 150 mm) salmon are found in the Estuary nearly year-round based on mid-water trawl sampling (Ganssle 1966, Messersmith 1966, Sasaki 1966, Aplin 1967, Kjelson 1982). Sampling in the 1960's and 1980 showed two migration peaks, one in the spring and a smaller one in the fall (Figures 3-1 and 3-2). Based on the size of the young salmon (Figure 3-2) and adult spawning times (Figure 2-3), large juveniles collected in the fall appear to be late fall subyearlings, or fall run yearlings that over-summered in the river further upstream. The larger fish observed in January through March are probably winter run or spring run smolts. The majority of outmigrants pass through the Estuary from April through June and are largely fall-run smolts. Very few juvenile salmon are present in the Bay or Delta between July and September (Figure 3-1) presumably due to high water temperatures in the Delta that may be lethal to salmon.

The numbers of fall-run juveniles passing Chipps Island between April and June are highly variable as measured by midwater trawl samples (Appendix 1) (Figures 3-3 and 3-4). About half of the fish are seen in May, while the remainder is split about equally between April and June (Table 3-1). A similar trend in

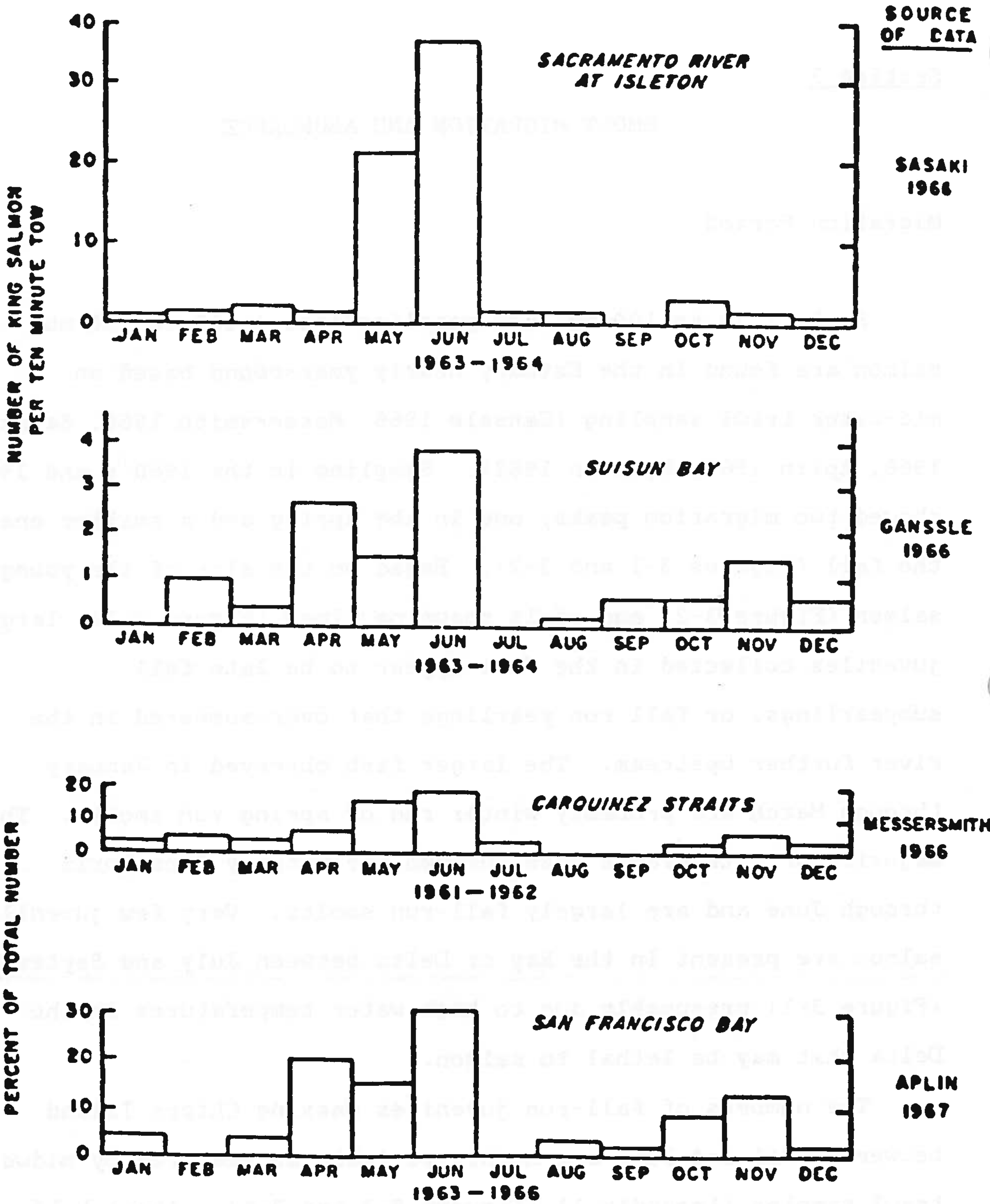

Figure 3-1. Seasonal abundance of juvenile chinook salmon in the Sacramento-San Joaquin Estuary and San Francisco Bay.

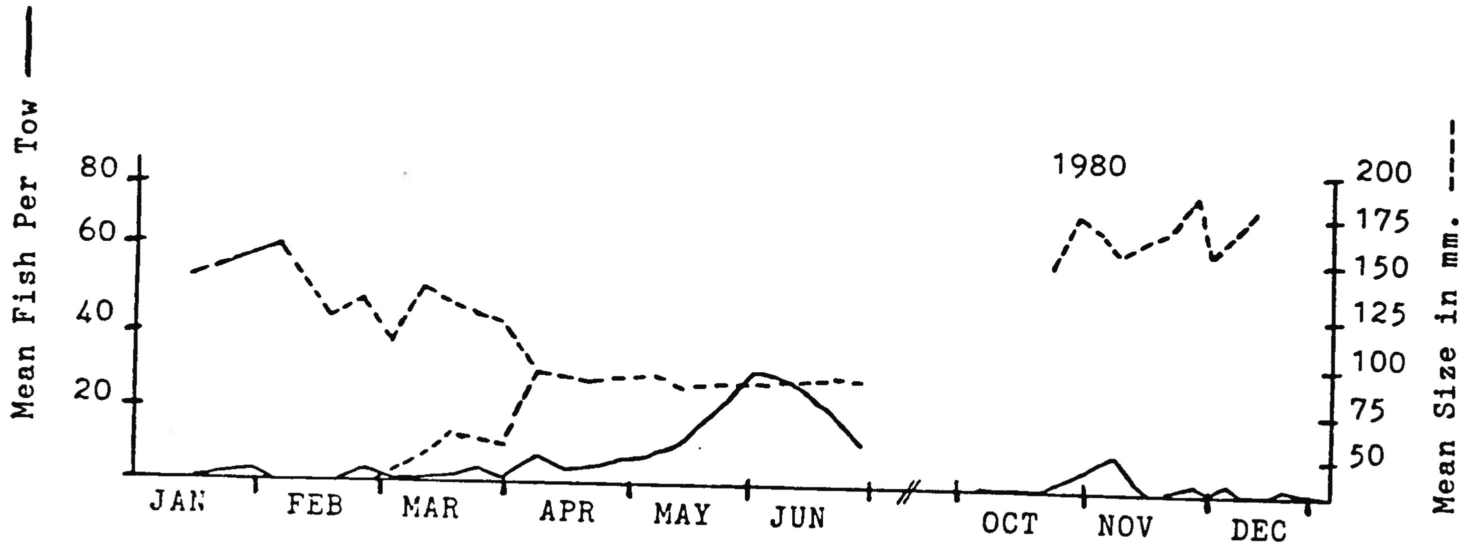

Figure 3-2. Mean midwater trawl catch per 20 minute tow at Chipps Island and mean size in millimeters of catch over time in 1980. Two size groups were observed in March and early April.

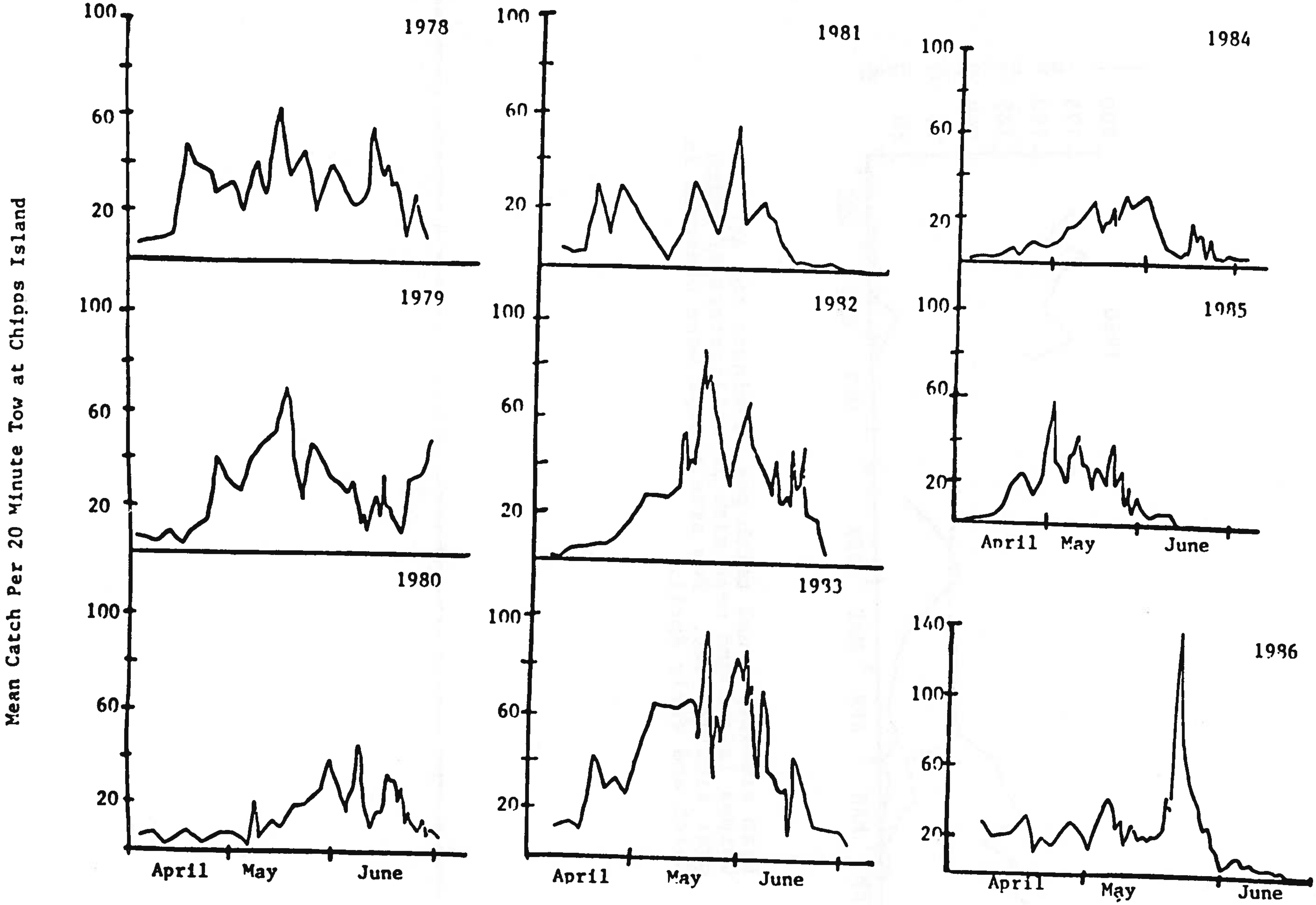

Figure 3-3. Mean midwater trawl catch per 20 minute tow at Chipps Island during the spring (April through June) 1978-1986.

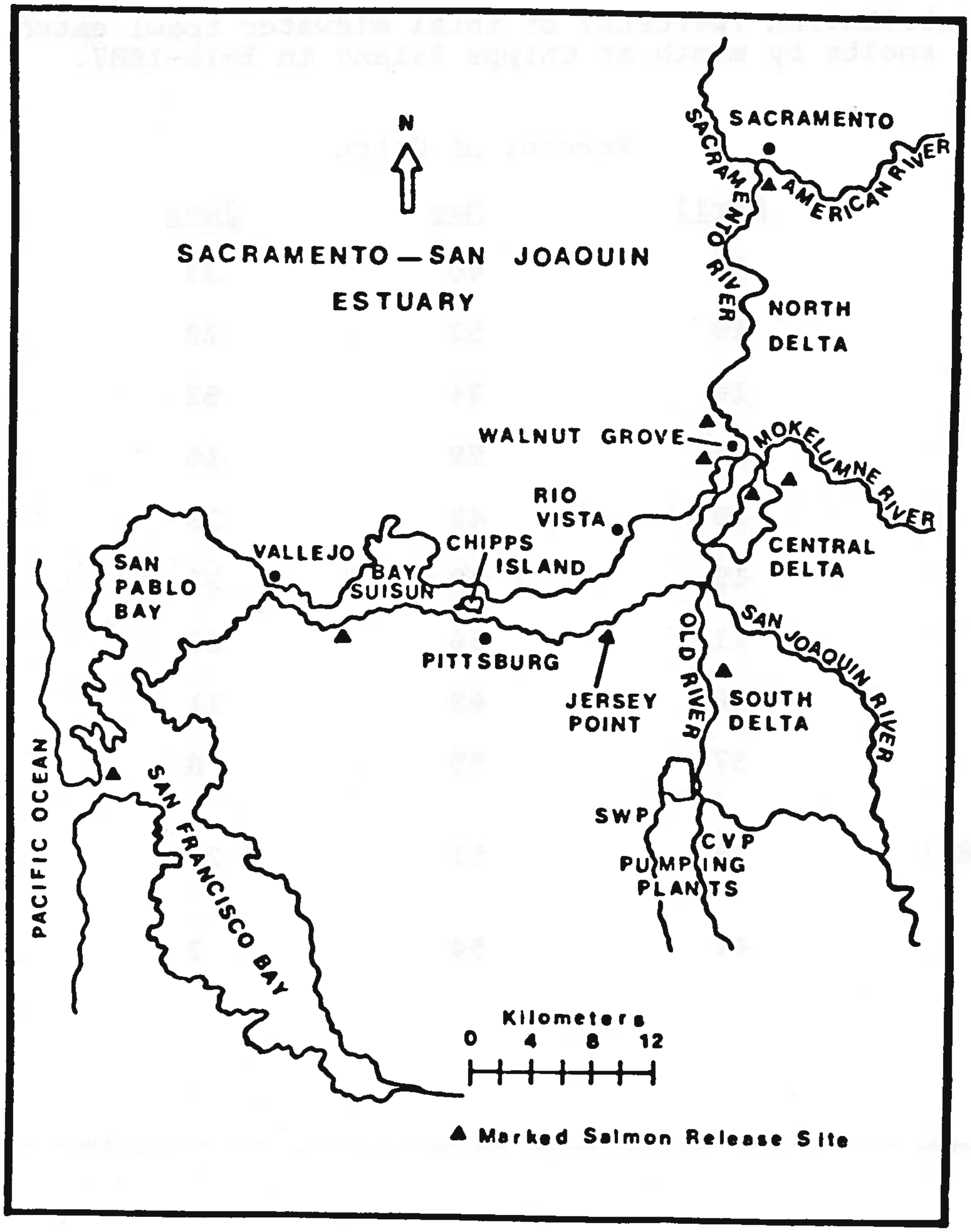

Figure 3-4. The Sacramento-San Joaquin Estuary of California including marked salmon release sites.

Table 3-1. Distribution (percent) of total midwater trawl catch of smolts by month at Chipps Island in 1978-1987.

	Percent of Catch		
Year	April	May	June
1978	27	40	33
1979	19	52	29
1980	14	34	52
1981	34	50	16
1982	18	49	33
1983	19	49	32
1984	11	66	23
1985	26	63	11
1986	37	55	8
$\bar{x}$ (78-86)	22	51	27
1987	44	54	2

outmigration periodicity also is seen from the midwater trawl samples taken at the Golden Gate Bridge since 1983 (Appendices 2 and 3).

The juvenile chinook in trawl samples at Chipps Island represent fish of both Sacramento and San Joaquin Valley origin, hence, potential differences in the timing of outmigration from the two drainages can not be determined but the San Joaquin outmigration appears earlier. Smolt migration out of the San Joaquin basin peaks about 1 May (CDFG Exhibit 15 regarding salmon needs in the upper San Joaquin drainage). Kelley et al. (1985) found that the majority of smolts left the American River between mid-May and mid-June.

We have found it difficult to predict exactly when peak fall run smolt outmigration may occur in a given year. A major problem is the mixing of smolts from both natural, instream spawning and those of hatchery origin in the Chipps Island midwater trawl catch. Major releases of fall-run hatchery smolts are made both above (in upper Sacramento River), in (at Rio Vista), and below the Delta (Suisun and San Pablo bays) (Table 3-2, Appendices 4 to 9). Most hatchery smolt releases begin in late May, thus smolts collected in April and early May are probably of natural origin while those later are a mix of both sources.

In 1985 and 1986, mass releases of Coleman Hatchery smolt production were made in the upper Sacramento at Red Bluff and in Battle Creek in the second week of May. Travel time between the upper Sacramento and Chipps Island is about 8 to 10 days. Hence,

Table 3-2. Fingerling and smolt and yearling fall run hatchery releases in millions by release year (Brood Year + 1) from Merced, Mokelumne, Coleman, Feather River and Nimbus Hatcheries from 1978 to 1985.

Fingerling and Smolts (450-45/lb)

Release Site	Release Year							
	1978	79	80	81	82	83	84	85
Above Delta	6.0	4.7	13.0	14.8	11.0	12.1	10.2	14.0
Rio Vista	7.7	8.1	3.9	0	2.2	.1	0	0
San Pablo Bay	.3	.2	.2	6.9	3.3	5.6	2.7	6.3
Total	14.0	13.0	17.1	21.7	16.5	17.8	12.9	20.3

Yearlings (<45/lb)

Release Site	Release Year							
	1978	79	80	81	82	83	84	85
Above Delta	2.7	2.6	2.3	1.8	1.7	1.7	.6	.4
Rio Vista	1.0	1.1	1.3	1.1	1.1	0	0	0
San Pablo Bay	.2	.2	.5	1.5	2.8	1.3	4.0	8.1
Total	3.9	3.9	4.1	4.4	5.6	3.0	4.6	8.5

the peak mid-water trawl catches in Figure 3-3 in late May of those years reflect the Coleman hatchery smolt release. This observation was confirmed by the trawl recoveries of tagged smolts that were part of those releases. These tagged smolts were recovered at the same time the sharp rise in catch occurred in late May.

Smolt Abundance

The relative abundance of smolts at Chipps Island since 1978 has ranged from a mean, April through June, midwater trawl catch of 10 fish per tow in 1984 to 48 fish per tow in 1983 (Table 3-3). Smolts from the Sacramento basin presumably dominate the index since from 78 to 99% of the fall-run spawning occurred there since the fall of 1977 to 1986 (Appendix 10, and Pacific Fisheries Management Council [PFMC]) 1986.

A smolt abundance index based on trawling at the Golden Gate Bridge from 1983 to 1986 is provided in Appendix 11.

An estimate of the total number of fall-run smolts passing Chipps Island between 1978 and 1986 has ranged from about 10 to 50 million fish.

Year:	1978	1979	1980	1981	1982	1983	1884	1985	1986
Total Smolt x 10^6:	32	22	20	9	39	53	12	21	23

These estimates were achieved by expanding the total trawl catch using the fraction of time sampled and a measure of the

Table 3-3. Mean catch of salmon smolts per 20 minute tow with our midwater trawl at Chipps Island during April, May and June from 1978 to 1987.

Year	April	May	June	Annual Mean[1/]	Mean Temp[2/]	Percent Diverted[3/]
1978	23.1	34.0	27.6	28	63	45
1979	14.9	41.6	23.2	25	63	55
1980	5.6	14.0	21.1	17	62	38
1981	17.3	25.3	8.3	15	67	55
1982	18.9	51.7	34.6	38	60	27
1983	24.8	65.0	42.8	48	57	23
1984	3.2	20.0	7.0	10	64	50
1985	10.3	24.7	4.1	20	66	61
1986	22.5	32.9	4.7	24	65	44
1987	15.4	19.3	0.8	16	NA	NA

1/ Total catch divided by the total number of tows for April through June.

2/ Degrees Fahrenheit, Sacramento River at Freeport (mean April through June).

3/ Percent of the Sacramento River diverted at Walnut Grove (mean April through June).

trawl's effectiveness to collect chinook smolts (Appendix 12). These estimates should be considered very rough approximations of the annual Central Valley fall-run smolt production. They represent natural as well as the hatchery smolt production that was released in or above the Delta but do not include hatchery fish released downstream of Chipps Island.

Survival rates appear to average about 2% during ocean residence between the time a smolt enters salt water to attaining adulthood (3 to 4 years old) based on ocean adult tag recoveries of CWT smolts released in Suisun Bay (Appendix 13, Figure 3-5). This indicates that an annual production of 10 to 50 million smolts per year would make from 200,000 to 1,000,000 adult chinook available to the ocean fishery (i.e., (10,000,000) times (.02) = 200,000 adults).

Smolt Abundance and Flow

The abundance of smolts at Chipps Island from 1978 to 1987 appears to be influenced by the rate of river flow. The correlation between smolt abundance and mean daily flow at Rio Vista during April through June has a correlation coefficient of 0.90 (Figure 3-6). While the correlation coefficient was significant, there was no apparent relation between flow and smolt abundance at flow levels between 7,000 and 19,000 cfs. When including data from the two high flow years, 1982 and 1983, a significant correlation observed. In those years we saw a major increase in outmigrants. Unfortunately, we did not have a mean

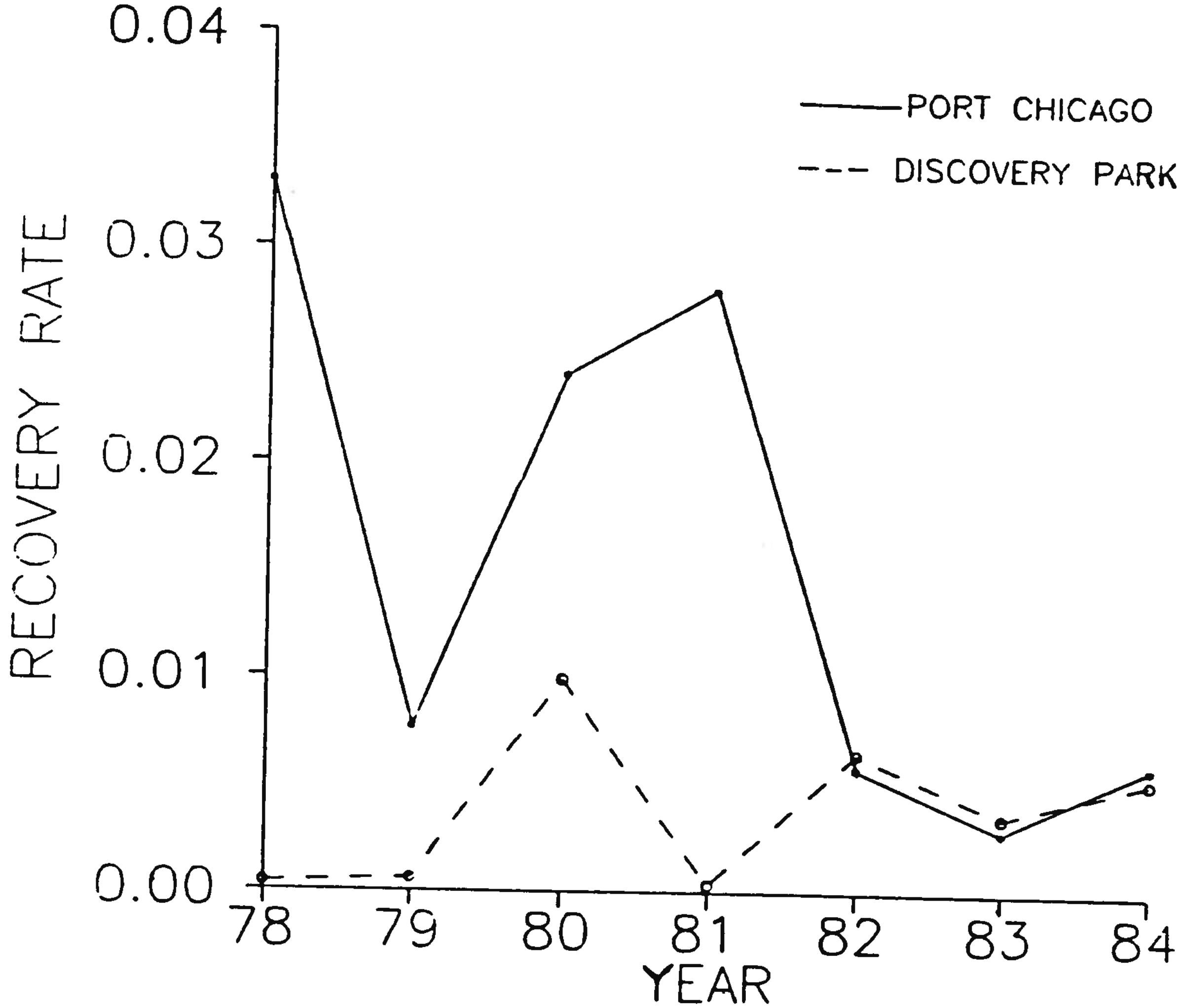

Figure 3-5. Recovery rates in the ocean fishery of CWT (coded wire tagged) salmon released from 1978 to 1984 at Discovey Park (Sacramento or Courtland (1983 and 1984) and Port Chicago (Suisun Bay).

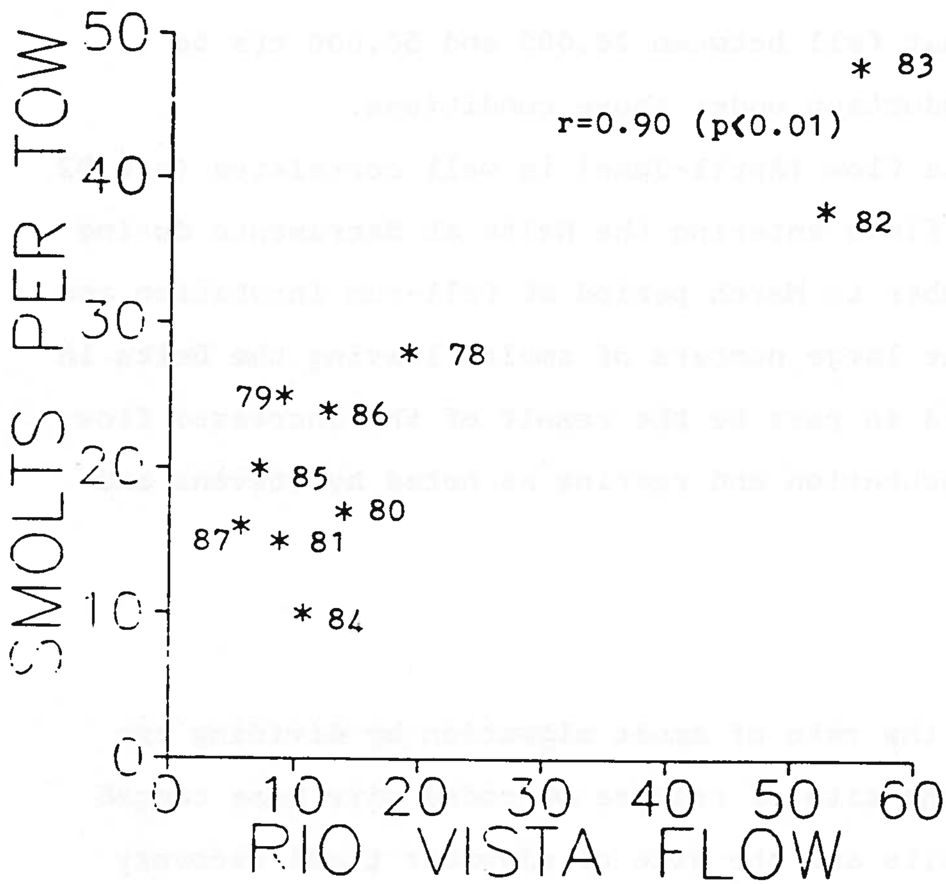

Figure 3-6. The relationship between the number of unmarked smolts caught per 20 minute midwater tow at Chipps Island versus mean daily Rio Vista flow (April through June) in cfs, from 1978 to 1987.

April-June flow that fell between 20,000 and 50,000 cfs to evaluate smolt production under those conditions.

Mean Rio Vista flow (April-June) is well correlated ($r=0.82$, $p<0.01$) with mean flows entering the Delta at Sacramento during the previous December to March period of fall-run incubation and rearing. Thus, the large numbers of smolts leaving the Delta in 1982 and 1983 could in part be the result of the increased flow upstream during incubation and rearing as noted by Stevens and Miller (1983).

Migration Rate

We estimated the rate of smolt migration by dividing the distance between the site of release of coded wire nose tagged (CWT) hatchery smolts and the site of midwater trawl recovery (Chipps Island or the Golden Gate) by the number of days between release date and the date the greatest number of tagged smolts were recovered. These estimates assume that the fish traveled the most direct route between the release and the recovery site and that hatchery fish migratory behavior is similar to natural smolts. Detailed migration rate data are found in Appendix 14.

We found that smolts migrated through the Bay and Sacramento Delta at a rate of from 3 to 20 miles per day (Table 3-4). There did not appear to be a difference between the smolt migration rate in the Sacramento Delta or San Francisco Bay but in the upper Sacramento, they migrated faster. This most likely reflects the dampening effect of tides on smolt migration through the Bay and

Table 3-4. Summary of migration rates through the Upper Sacramento River, Delta and San Francisco Bay estimated from CWT salmon released in those areas and recovered by trawl at Chipps Island or the Golden Gate Bridge from 1978 to 1987.1/

Migration Rate in Miles Per Day

Year	Upper River (Battle Creek)2/	Delta (Sacramento or Courtland)2/	San Francisco Bay (Port Chicago)3/
1979		8.5	
1980		10.9, 5.2	
1981		7.5	
1982		20, 7.5, 6.3	
1983	57.4	3.4	4.0
1984		5.7	8.0, 6.7
1985	35.8	5.7	4.4
1986	41.0	4.9	10.0
1987	41.0	5.7, 6.8	

1/ Site of CWT smolt release in parenthesis.

2/ Recoveries made by trawl at Chipps Island.

3/ Recoveries made by trawl at Golden Gate.

Delta. We found no relationship between smolt migration rate and the magnitude of flow in either the Sacramento Delta or the Bay. Even during the spring of 1982 and 1983 when river flows were very high, migration rates remained similar to that of the other dryer years (Table 3-4). Migration from the upper Sacramento to Chipps Island ranged from 36 to 57 miles per day. In 1983 it was more rapid than in 1985, 1986 or 1987 suggesting that the increased flows in 1983 increased migration rate down the main Sacramento River above the Delta (Table 3-4).

By evaluating migration rates and distances traveled we found that on the average, fall-run smolts pass through the entire Delta and Bay in about two weeks while migration from the upper Sacramento to the Delta takes about a week.

Section 4

SMOLT SURVIVAL

We compared smolt survival under varied conditions in an attempt to identify the factors operating in the Estuary that influence the number of smolts entering the ocean. Survival experienced by smolts in the Estuary will have a direct affect on the number of adult salmon that are produced.

Smolt survival in the Estuary was estimated by using two separate approaches using the recovery of marked hatchery smolts.

The first approach was based on recoveries of marked adult chinook from the ocean fishery two to four years after they were released as marked smolts. They were used to estimate survival through the Delta between the town of Sacramento (at the northern edge of the Delta) and Suisun Bay (Figure 3-4).

The fraction surviving between Sacramento and Suisun Bay, S_0, equals $\frac{R_1}{M_1} \div \frac{R_2}{M_2}$ where R_1 is the number of marked adults recovered from the Sacramento release; M_1 is the number released at Sacramento; R_2 is the number of marked adults recovered from the Suisun Bay release; and M_2 is the number released in Suisun Bay. We assume both release groups survive the same after passing Suisun Bay. Hence differences in the two recovery rates reflect mortality of the Sacramento group as they migrated through the Delta. The fact that these survival estimates are based on a ratio allows us to make comparisons between years because the effects of variation in ocean survival on Delta survival estimates have been factored out. Detailed marked smolt release and adult recovery information, resulting Delta survival estimates and methods are provided in Appendix 13 and 15.

The second approach used to estimate smolt survival, S_T, was based on midwater trawl recoveries of coded wire tagged smolts at Chipps Island. These fish were released further upstream in the Delta. Details of the methods, and release and recovery data for this approach are provided in Appendices 16 and 17.

Smolt Survival in the Sacramento River Delta

Effects of Flow

Based on ocean tag recoveries, the survival of smolts through the Delta from Sacramento to Suisun Bay was related to mean daily Sacramento River flow at Rio Vista (Figure 4-1). Survival, S_O, increased rapidly with an increase in flow from about 5,000 to 21,000 cfs where survival appears maximum. Smolt survival remains at about 100% at Rio Vista flows over 21,000 cfs. Survival values over the theoretical maximum of 100% for 1982 and 1983 may reflect sampling imprecision or some unknown bias. This indicates we should view all values as indices of survival rather than as absolute values. Smolt survival measure, S_O, is believed to be a closer representation of absolute survival than S_T, since bias associated with trawl net avoidance 's eliminated.

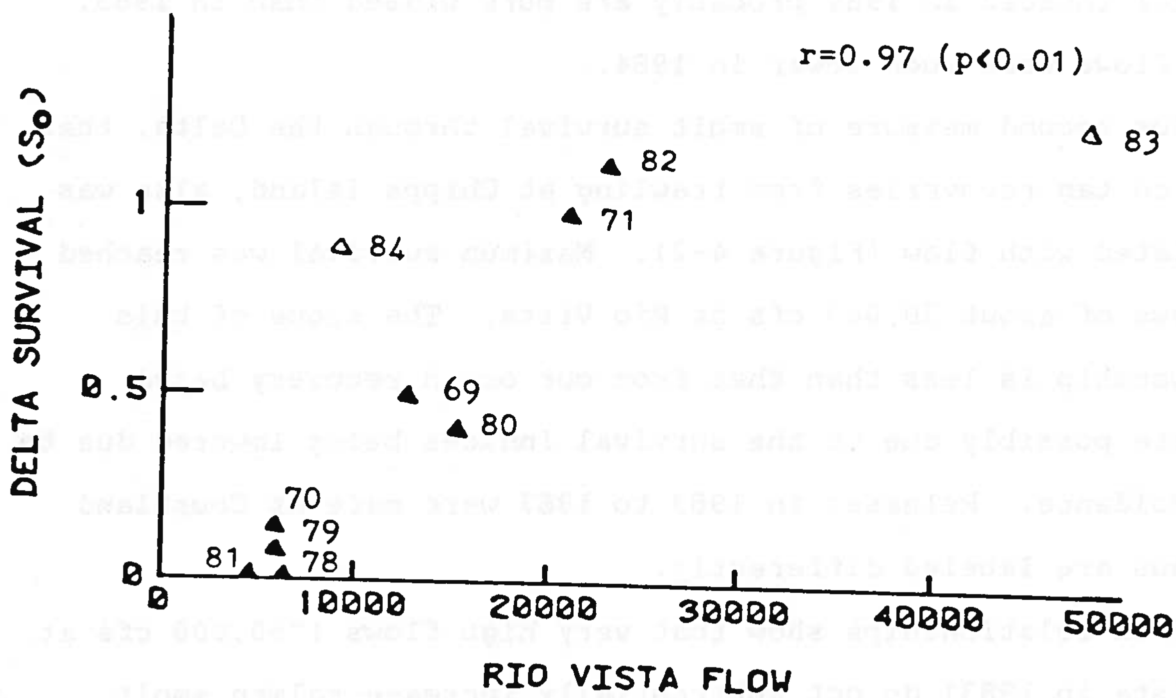

Figure 4-1. The relationship between Delta smolt survival (S_0) and mean daily Rio Vista flow during the time the marked salmon were migrating through the Delta. Survival (S_0) is based on ocean tag recovery rates of Feather River Hatchery salmon planted at Sacramento or Courtland (1983 and 84) and Port Chicago.

The values for 1983 and 1984 probably are biased high relative to other years since they were planted about 26 miles downstream of Sacramento (at the "Courtland" site) and thus traveled a shorter distance than smolts released in earlier years at Sacramento. They are labeled differently in Figure 4-1. Survival indices in 1984 probably are more biased than in 1983, since flows were much lower in 1984.

Our second measure of smolt survival through the Delta, that based on tag recoveries from trawling at Chipps Island, also was correlated with flow (Figure 4-2). Maximum survival was reached at flows of about 30,000 cfs at Rio Vista. The slope of this relationship is less than that from our ocean recovery based estimate possibly due to the survival indices being lowered due to net avoidance. Releases in 1983 to 1987 were made at Courtland and thus are labeled differently.

Both relationships show that very high flows (~50,000 cfs at Rio Vista in 1983) do not substantially increase salmon smolt survival over that observed at from 20,000 to 30,000 cfs but that increases in flow up to those latter levels are highly beneficial.

Validity of Survival Indices

We attempted to evaluate any potential biases and imprecision characterizing our survival measures. We evaluated the unavoidable differences in fish release size, dates of release and temperature conditions at the release sites between the two release groups (Sacramento and Suisun Bay) in a given year and no biases were identified (Appendices 18 and 19). Data was

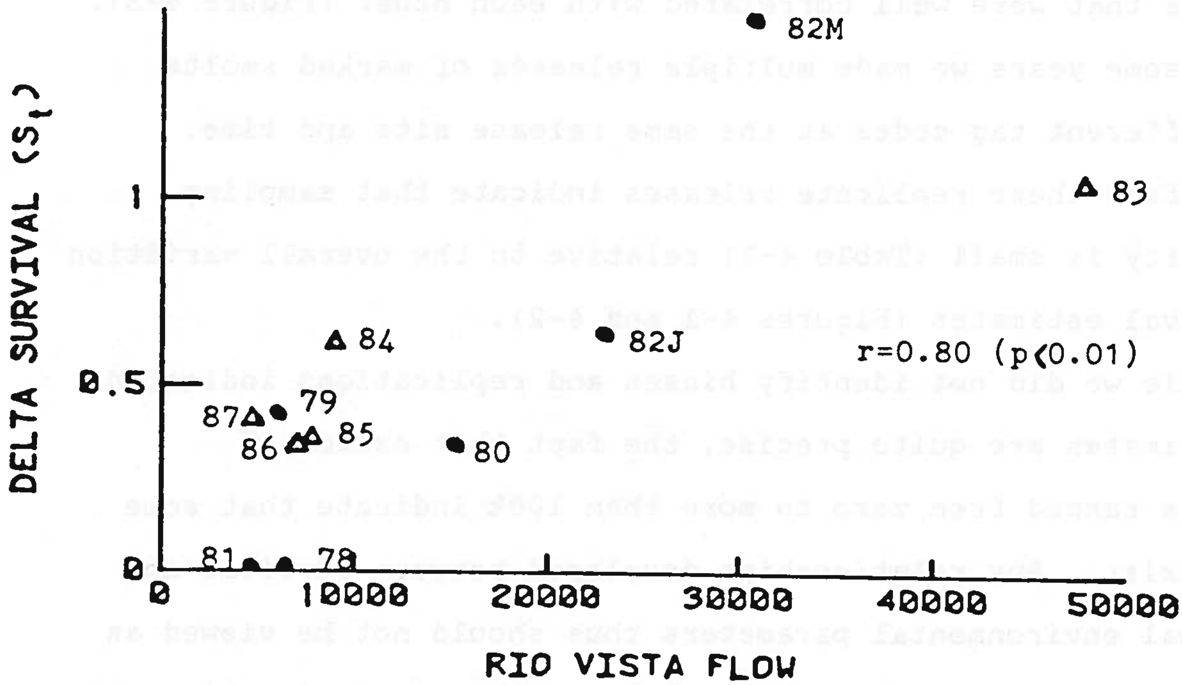

Figure 4-2. The relationship between Delta smolt survival (S_T) based on midwater trawl recoveries at Chipps Island of Feather River Hatchery smolts planted at Sacramento or Courtland (1983 through 1987) and mean daily Rio Vista flow during the time the marked salmon were migrating through the Delta.

insufficient to evaluate potential site differences in fish predation or effects associated with food abundance and salinity, but there is no reason to believe they would be sufficient to cause a spurious relationship between survival and flow. Additional evidence that these survival measures are unbiased is the fact that the two, essentially independent methods yielded survivals that were well correlated with each other (Figure 4-3).

In some years we made multiple releases of marked smolts using different tag codes at the same release site and time. Returns from these replicate releases indicate that sampling variability is small (Table 4-1) relative to the overall variation in survival estimates (Figures 4-1 and 4-2).

While we did not identify biases and replications indicated that estimates are quite precise, the fact that estimated survivals ranged from zero to more than 100% indicate that some errors exist. Any relationships developed between survival and individual environmental parameters thus should not be viewed as precise predictive models. Nevertheless, these relationships are useful in assessing the needs of chinook salmon. They also are useful in making comparisons of relative survival under different conditions.

Finally, we acknowledge that all our marked/recovery experiments with both smolt and fry use hatchery produced salmon that are released sites with little acclimation to the natural water temperatures. The question is often raised, do hatchery fish behave and survive as wild fish do? We do not know. Our

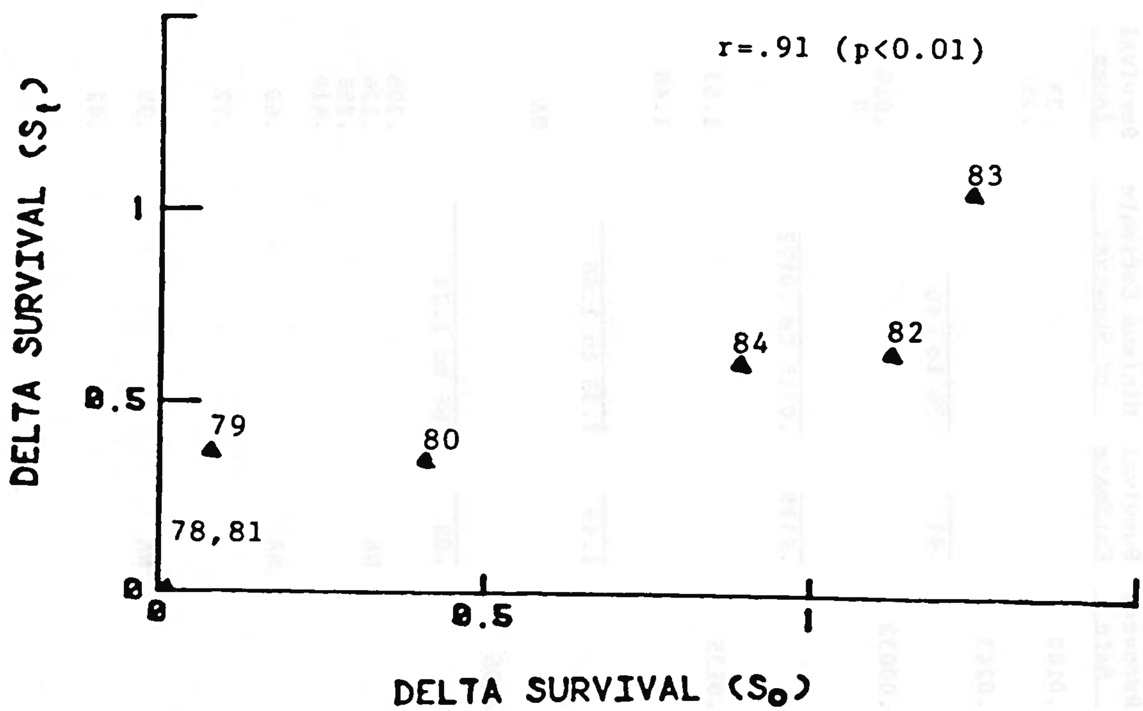

Figure 4-3. Ocean tag recovery estimate of Delta smolt survival (S_O) versus midwater trawl tag recovery estimate of Delta smolt survival (S_T).

Table 4-1. Summary of the ranges in recovery rates of marked fish from both the adult (ocean) and trawl (juvenile) recoveries, and the associated variability around estimates of survival when multiple tag codes are used.

			Adult Recovery Estimate				Trawl Recovery Estimate			
Year	Release Site	CWT Code	Recovery Rate	Mean Recovery Rate	Survival Estimate	Maximum and Minimum Estimate of Survival	Survival Index	Mean Survival	Sd	Mean Survival Index ± 1 Sd[1/]
1980	Sacramento	6-62-8	.0107	.0100			.33	.34	.014	.33 to .35
	Sacramento	6-62-11	.0092				.35			
	Port Chicago	6-62-09	.0232	.0243						
	Port Chicago	6-62-12	.0253							
					.41	.36 to .46				
1981	Sacramento	6-62-14	.00034	.00033			.016	.008	.011	0 to .019
	Sacramento	6-62-17	.00032				0			
	Port Chicago	6-62-15	.0279							
					.0118	.0115 to .0122				
1982	Sacramento (CNFH)	6-62-18	.0120	.0135			1.53	1.51	.035	1.48 to 1.54
	Sacramento (FRH)	6-62-20	.0150				1.48			
	Port Chicago (CNFH)	6-62-19	.0091							
					1.49	1.33 to 1.66				
1984	Courtland	6-62-27	.0053				NA			
	Port Chicago	6-62-31	.0040	.006						
	Port Chicago	6-62-37	.0080							
					.89	.66 to 1.33				
1985	Courtland	6-62-38			NA		.395	.30	.13	.17 to .43
	Courtland	6-62-39					.126			
	Courtland	6-62-40					.258			
	Courtland	6-62-41					.410			
1987	Courtland (gates closed)	6-62-53			NA		.60	.66	.085	.57 to .75
	Courtland (gates closed)	6-62-54					.72			
	Courtland (gates opened)	6-62-56			NA		.39	.41	.021	.39 to .43
	Courtland (gates opened)	6-62-57					.42			

1/ Sd = Standard Deviation

attempts to quantify this concern with limited experimental data, contacts with fellow biologists in the United States and Canada and review of the scientific literature has been fruitless. Our sense is that recently planted hatchery fish would not survive as well as wild fish even though size and condition appear identical. However, even with some potential bias of this type, we believe our use of the survival measures, as indices, enable us to gain valuable information about the factors influencing survival of all juvenile salmon in this Estuary. The relationships between unmarked salmon abundance and flow, temperature and diversion provide evidence that unmarked natural salmon also respond to these three environmental factors similarly to the marked hatchery fish.

Mechanisms Underlying the Flow:Survival Relationship

Two reasons could explain why increased flow as an independent mechanism would improve survival.

Turbidity

Increased turbidity associated with high flow could lessen the effectiveness of sight-feeding predators and thus decrease smolt mortality. Turbidity in the Delta increases with higher river runoff but we do not have direct measures of predation to test this hypothesis.

Toxicity

High flows would dilute harmful pollutants and thus increase salmon smolt survival. This hypothesis also cannot be tested.

Temperature

We found that smolt survival, S_0, in the Delta was negatively correlated to mean water temperature between Sacramento and Suisun Bay (Figure 4-4). The highest temperatures experienced by smolts are in late May and June (Appendix 20).

Temperatures acutely lethal to chinook salmon smolts are about 76°F, (Brett et al. 1982, Orsi 1971). Chinook salmon, are stressed as temperatures rise and temperatures over 65°F are usually considered undesirable for juvenile chinook (Brett et al. 1982, Banks et al. 1971). Energy needs also increase as temperatures rise (Brett et al. 1982) and food may be more limiting as temperatures increase (See Appendix 20). Chinook smolts consume both insects and zooplankton during their estuarine migration (Kjelson et al. 1982). We do not have sufficient data to evaluate if food densities of either type are limiting to salmon during their week long migration through the Delta but it is possible.

Since many of our CWT smolt releases were made from mid May to early June when temperatures were often high, it is possible that the flow:survival relationship in Figure 4-1 is not accurate for April and early May when temperatures are lower. If high temperatures are a major cause of the lower survival at low flows

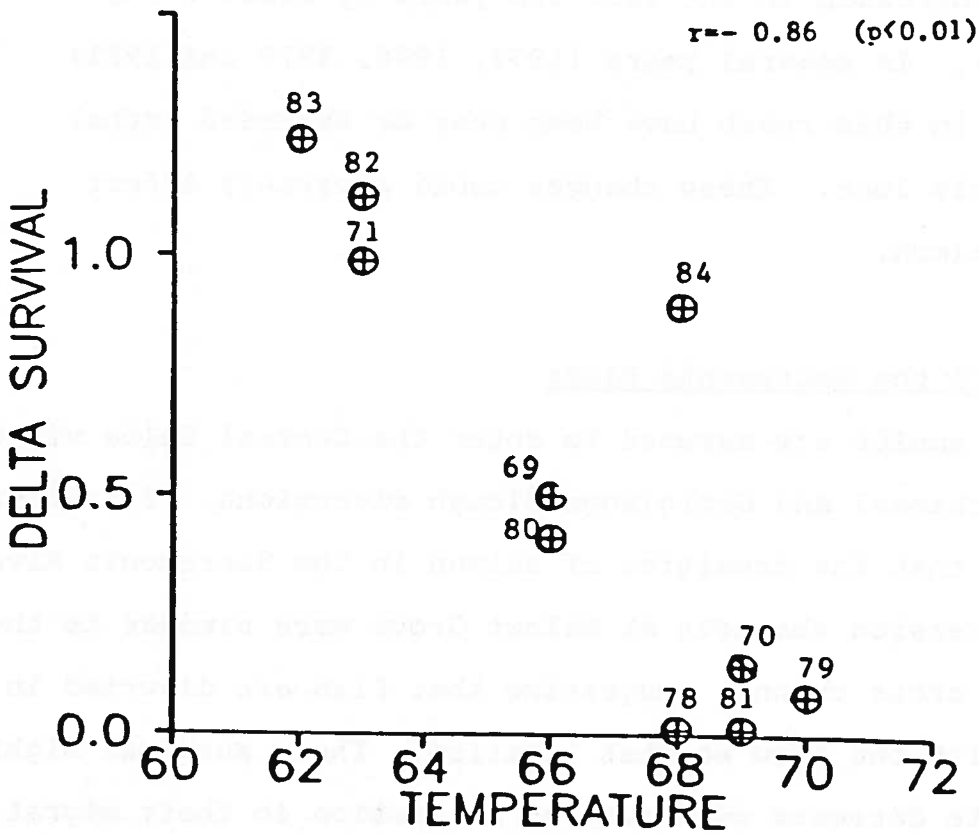

Figure 4-4 Delta smolt survival (S_o) based on ocean tag recoveries of marked salmon, versus mean temperature from Sacramento to Port Chicago during the time the marked fish are migrating through the Delta. Temperature was taken at Freeport in 1969.

in Figure 4-1 then the smolt survival for April and early May would be expected to be somewhat higher at low flows than shown in Figure 4-1.

Average late May and June water temperatures in the lower Sacramento River between the mouth of the Feather and American rivers have increased in the last ten years by about 2-3^{o}C (Appendix 20). In several years (1977, 1978, 1979 and 1981) temperatures in this reach have been near or exceeded lethal levels in early June. These changes could adversely affect outmigrant salmon.

Diversions Off the Sacramento River

Chinook smolts are assumed to enter the Central Delta via the Delta cross channel and Georgianna Slough diversions. Schaffter (1980) found that the densities of salmon in the Sacramento River above the diversion channels at Walnut Grove were similar to those in the Delta cross channel suggesting that fish are diverted in proportion with the flow at that location. Their survival might be expected to decrease with such an alteration in their migration route since the smolts would travel a longer route where they would be exposed to increased predation, higher temperatures, a greater number of agricultural diversions and a more complex channel configuration making it more difficult to find their way out to sea. In addition, upon reaching the mouth of the Mokelumne on the lower San Joaquin River they are often exposed to upstream (reverse) flows moving to the south via Old and Middle Rivers toward the Project pumping plants and sometimes to reverse flows in the San Joaquin River itself.

Smolt survival in the Delta was correlated with the percentage of water diverted from the Sacramento River at Walnut Grove (Figures 4-5 and 4-6). The percent diverted was calculated from the ratio of the sum of the estimated flows in the Cross channel and Georgiana Slough over the flow in the Sacramento River just above the cross channel times 100. The flow in the Sacramento River was calculated by subtracting the flows in Steamboat and Sutter Sloughs from Sacramento River flow at I Street in Sacramento. Channel flows were either DAYFLOW values or based on formuli provided by the Department of Water Resources (Appendix 21).

We evaluated the impact of salmon being diverted off the Sacramento River by comparing the survival indices of CWT smolts released 3.5 miles above and 3 miles below the diversion point at Walnut Grove. We also made tagged smolt releases in the Mokelumne River in the Central Delta (Figure 4-6). Survival of the various release groups was based on the Chipps Island trawl recovery of CWT smolts released from 1983 to 1987. Detailed recovery and survival information is provided in Appendices 17 and 22.

We found that in three of four years (1985, 1986, and 1987), that under high diversion rate (>60%) with the Delta Cross channel gates open, the survival of smolts released above the diversion was about 50% less than for those released below the diversion Table 4-2). When the cross channel gates were closed, there was no difference in survival of these two groups during the high flow

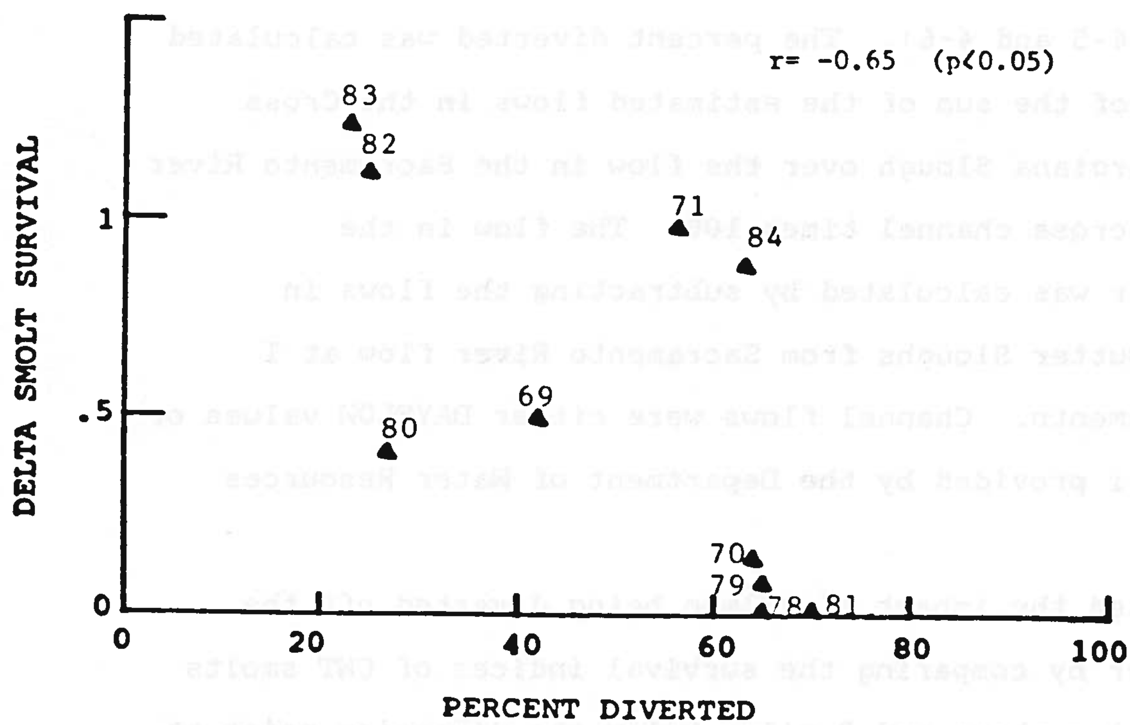

Figure 4-5. Delta smolt survival (S_0) based on ocean tag recoveries of marked salmon versus the percent diverted off the Sacramento River into the Cross Channel and Georgiana Slough at Walnut Grove during the time the marked fish were migrating past Chipps Island.

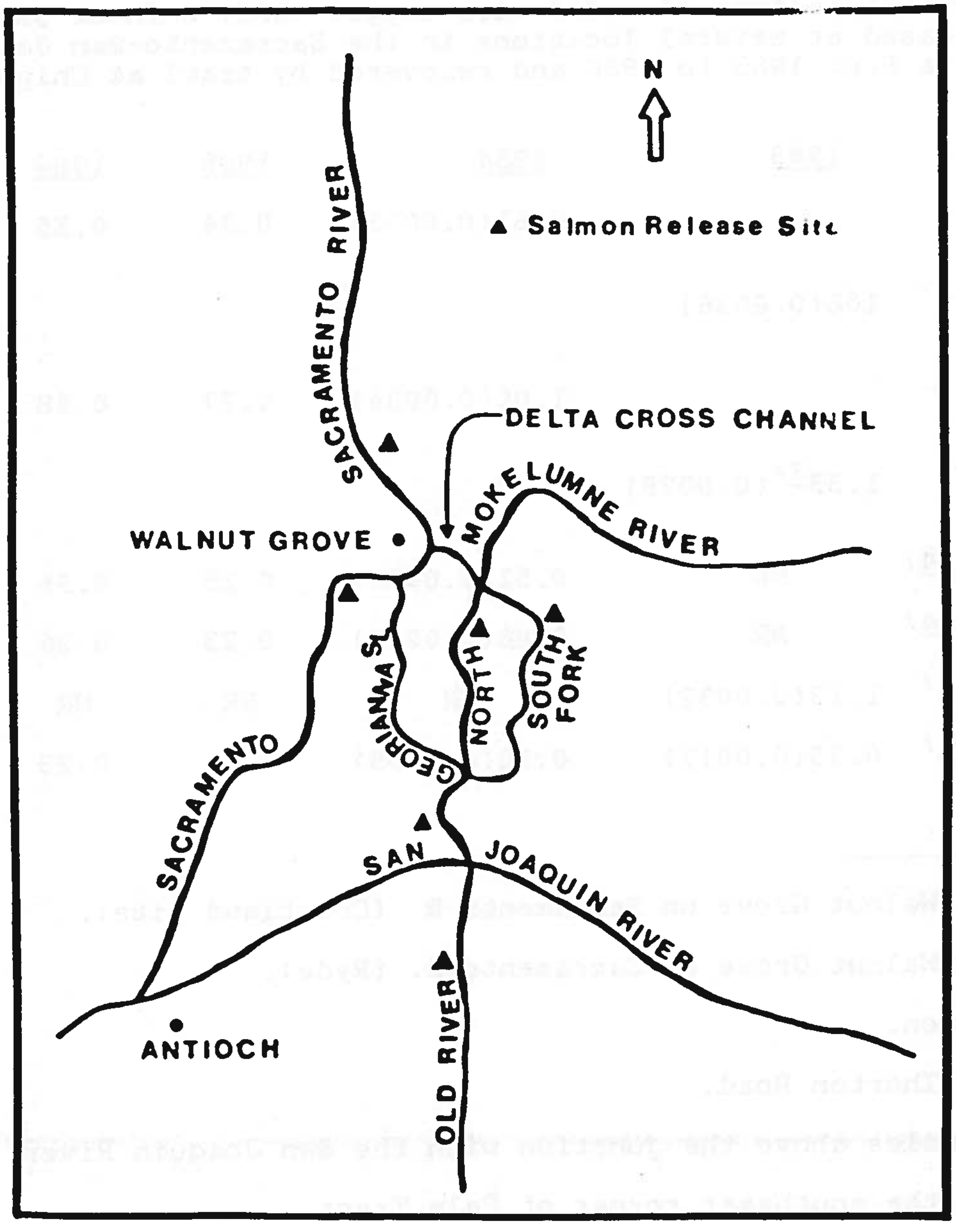

Figure 4-6. Detail schematic of the central portion of the Sacramento-San Joaquin Delta including major water diversion channels and coded wire tagged salmon release sites.

Table 4-2. Survival indices of coded wire tagged (CWT) chinook smolts released at several locations in the Sacramento-San Joaquin Delta from 1983 to 1986 and recovered by trawl at Chipps Island.

Release Site	1983	1984	1985	1986	1987
Above Diversion[1/] gates opened		0.61(0.0053)	0.34	0.35	0.40
Above Diversion gates closed	106(0.0036)				0.67
Below Diversion[2/] gates opened		1.05(0.0034)	0.77	0.68	0.88
Below Diversion gates closed	1.33[3/](0.0029)				0.85
N. Fk. Mokelumne R.[4/]	NR	0.51(0.0036)	0.28	0.36	NR
S. Fk. Mokelumne R.[4/]	NR	0.86(0.0049)	0.23	0.26	NR
Lower Mokelumne R.[5/]	1.13(0.0032)	NR	NR	NR	NR
Lower Old River R.[6/]	0.33(0.0011)	0.16(0.0005)	0.21	0.23	NR

1/ 3.5 miles above Walnut Grove on Sacramento R. (Courtland site).

2/ 3.0 miles below Walnut Grove on Sacramento R. (Ryde).

3/ Release at Isleton.

4/ Release site at Thorton Road.

5/ Release site 2 miles above the junction with the San Joaquin River.

6/ Release site at the southeast corner of Palm Tract.

NR= No Release.

Values in parenthesis are expanded CWT recovery rates from the ocean fishery.

year of 1983, and about a 25% difference in the very low flow year of 1987. There was no apparent difference in survival between these groups in 1984 when the cross channel was open which is unexplained.

Release temperatures at the sites above and below the diversion point in a given year were nearly identical indicating that the survival differences were due to the diversion process and not to temperature differences in the Sacramento River (Table 4-3). The 1987 data indicate that closing the cross channel even during low flow years can yield a major increase in Delta smolt survival.

Tagged smolts released in the Central Delta, just east of Walnut Grove, in the north and south forks of the Mokelumne River (mouth of the Mokelumne in 1983), represented smolts that had been diverted off the Sacramento River. These smolts had survivals slightly lower than those released above the point of diversion during 1985 and 1986 presumably because some fraction of the groups released above the diversion point remained in the Sacramento River and experienced better survival as indicated by the survivals of those released below the diversion point. This confirms that fish once diverted into the Central Delta have poorer survival than those remaining in the Sacramento River.

Smolts moving down the Mokelumne have the opportunity to turn west when they enter the lower San Joaquin or to continue into the southern Delta toward the Project pumping plants. In low runoff

Table 4-3. Diversion, flow and temperature conditions in the north, central and southern Sacramento-San Joaquin Delta from the time the marked Courtland fish were released until they had passed Chipps Island, from 1983 to 1987.

	1983	1984	1985	1986	1987-O[f]	1987-C[f]
Percent Diverted[a]	23	62	65	64	69	69
Sacramento R. Flow[b]	47746	9041	7168	7734	5273	5160
San Joaquin Flow[c] (Q west)	35773	680	7518	4767[g]	46[g]	-1001[g]
Temperature[d] above Diversion	60	66	64	73	66.5	66.5
Temperature below Diversion	61	66	66	74	64	67
Temperature, Mokelumne R.	62	70	64	70	NR[h]	NR
Temperature, Lower Old R.	63	75	68	74	NR	NR

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a/ from Sacramento River at Walnut Grove

b/ at Rio Vista (cfs)

c/ at Jersey Point (cfs)

d/ °F at release site

e/ mean North Fork and South Fork Mokelumne River

f/ O = Cross channel gates opened
C = Cross channel gates closed

g/ estimates of Q west are from DWR and does not include input form east side streams, thus it is probably bias low by about 10-20%. Information obtained for these three estimates were obtained from Jim Snow DWR operations; pers. comm.

h/ NR = no release

years as 1984, 1985 and 1987, the direction of the net lower San Joaquin flow (at Jersey Point) is often reversed or very low which would be expected to hinder smolt migration to the ocean. This may partially explain the low survival of tagged smolts released in the Mokelumne in 1985 and above the Cross channel in 1987 with the gates opened, since San Joaquin flow was reversed or only slightly positive (Table 4-3). During 1984 that flow was only slightly higher than in 1985 yet survival in 1984 was much highter (Table 4-3). Hence, hydrology in the lower San Joaquin does not seem to explain the better survival in 1984.

An additional group of CWT smolts was released in lower Old River south of the San Joaquin River (Figure 4-6). These releases were designed to represent Sacramento River smolts that had migrated via reverse flows into the south Delta toward the Project pumps.

Their survival was the lowest of all release groups for all years and probably reflects more harsh conditions in the southern Delta. Higher water temperatures and reverse flows (Tables 4-3 and 4-4), predation near the south Delta Project fish screens and the fish screen salvage process itself all could contribute to higher smolt mortality in the southern Delta (see CDFG Exhibit Number 17).

The similar survivals of the Mokelumne release groups compared to those from the Lower Old River in 1985 and 1986 also suggest that some of the smolts moving down the Mokelumne were carried into Old River. The greater difference betwe'n the two

Table 4-4. Average temperatures in degrees Centrigrade plus or minus 1 standard deviation for April through June from 1971 to 1985 for stations throughout the Delta.1/

Months	Central Delta	North Delta2/	Southern Delta	Chipps Island	Fish Facility
April	15.36 ±1.37	13.73 ±2.05	15.73 ±1.78	15.1 ±1.39	16.14 ±1.62
May	18.28 ±1.54	16.5 ±1.76	19.11 ±1.58	17.90 ±1.17	19.38 ±1.02
June	21.16 ±1.31	20.10 ±1.70	22.05 ±1.58	20.57 ±1.21	22.70 ±1.33

1/ Data from California Department of Water Resources, water quality monitoring survey.

2/ At Greens Landing near Hood on Sacramento River.

groups in 1984 could be due to the nearly lethal (75°F) Lower Old River temperature (Table 4-3). We do not know why the survival of the lower Old River group was low in 1983, when flows and temperatures appeared favorable.

The salvage process at the water projects' (SWP/CVP) fish screens provides a means to estimate the minimum numbers of tagged smolts that are carried into the southern Delta from the Sacramento Basin. This is a minimum estimate since mortalities in the southern Delta prior to salvage would not be included. Intensive sampling for tagged smolts at the salvage facilities in 1985, 1986 and 1987 indicated that a very small percentage (0 to 0.36%) of the CWT smolts released in the Sacramento River (just above the Walnut Grove diversion) or in the forks of the Mokelumne River (Table 4-5) were salvaged in the southern Delta. While these percentages are small, given that there are tens of millions of fall-run smolts leaving the Sacramento Basin each spring, the number salvaged that were from the Sacramento could be large. If, for example 20 million smolts left the Sacramento, it is reasonable that as many as 72,000 of the salmon salvaged in the south Delta facilities might be from the Sacramento (0.0036 times 20 million). This is a significant fraction (31%) of the average annual smolt salvage (230,000)in April through June for the years 1970 to 1985 (Appendix 23).

It is interesting to note that the majority of these tag recoveries were made at State Water Project facility (Table 4-5) suggesting that the fish from the Sacramento Basin are more likely

Table 4-5. Coded wire nose tagged smolts (CWT) released in the North and Central Delta and recovered during intensive sampling at the CVP and SWP Fish Facilities in 1985, 1986 and 1987[1/].

Year and Release Location	CWT Code	Number Released	Expanded Number Recovered from the CVP	Expanded Number Recovered from the SWP	Unexpanded[2/] Other	Total	Fraction Recovered
1985							
SF Mokelumne	6-62-34	100,386	9	80	8	97	.00097[3/]
NF Mokelumne	6-62-36	101,237	4	10	12	26	.00026[3/]
Courtland	6-62-38 6-62-39 6-62-40 6-62-41	107,162	0	0	4	4	.00004[3/]
1986							
SF Mokelumne	6-62-46	103,750	12	360	--	372	.00359
Courtland	6-62-43	104,000	8	0	--	8	.00008
1987							
Courtland gates closed	6-62-53 6-62-54	49,781 50,421	26 12	28 114	-- --	54 126	.0011 .0025
Courtland gates opened	6-62-56 6-62-57	49,083 51,836	0 6	0 180	-- --	0 186	0 .0036
Ryde gates closed	6-62-55	51,103	6	0	--	6	.0001
Ryde gates opened	6-62-58	51,008	0	0	--	0	0

1/ These represent expanded numbers of salvaged fish based on fraction of time sampled.

2/ These fish were recovered in a handling and trucking experiment in 1985 at the SWP facility from 5-16 to 6-13 and could not be expanded in any way.

3/ This is considered a minimum fraction for 1985, because we stopped sampling 3 days after the Delta fish began arriving at the fish facilities. Other sporadic sampling at the facilities after 5-15 indicated we missed the majority of marked Delta fish coming through the facilities.

to be seen there than at the Federal (CVP) facility. The opposite is true for recoveries of tagged fish released in the upper Old River representing fish from the San Joaquin Basin, i.e., more of them are seen at the CVP facility (See Appendices 24a-e).

Application of Smolt Survival Relationships

The survival estimates in Figure 4-1 do not represent the annual survival of the total population of fall-run smolts migrating through the Delta, but only that of each experimental release of marked fish at a specific time. To estimate the overall survival of the population each year, we calculated an annual (weighted) estimate of fall-run smolt survival through the Sacramento Delta using the survival:flow relationship on Figure 4-1. Flow in the relationship is meant to be an "index parameter" representing the net survival response of smolts to changes in flow, temperature and diversion. This approach yields some error since as noted earlier, survival was measured during May and June and not April when lower water temperatures could have raised survival and altered the relationship shown in Figure 4-1. It is possible that if we had measured survival at the low flows (<10,000 cfs) in April of 1970, 78, 79, and 81 that those respective survival values in Figure 4-1 would be somewhat higher. We believe it likely though, that low flow and high diversions in April can limit smolt survival.

We used the equation, smolt survival (Y) = 0.000056x - 0.258 for Rio Vista flows (X) between about 4,600 and 22,000 cfs (Figure 4-1). A Delta smolt survival index value of 1.0 was assumed when flows were above 22,000 cfs. Data from 1982 to 1984 were not used in the equation since 1982 and 1983 were over 1.0 which we considered maximum survival, and because 1983 and 1984 data reflects releases made at just above Walnut Grove ("Courtland") rather than at Sacramento. Survivals were calculated from the mean flow at Rio Vista each month and then multiplied by the average percentage of smolts collected at Chipps Island that month (Table 3-1). The estimates annual weighted survival indices of smolt population for the years 1978 to 1986 (Table 4-6) ranged from 0.16 in 1985 to 1.0 in 1983. The annual smolt survival indices during 1978, 1979 and 1981 are not near zero as depicted in Figure 4-1 but range at a minimum of from 0.27 to 0.65 (Table 4-6).

We used the same equation described above to estimate the smolt survivals that are presently provided under the salmon and striped bass flow standards in the 1978 Delta Plan. Striped bass standards are for Delta outflow (May and June) thus we transformed them to Rio Vista flows in May and June using correlation between the two flows in the 2 months (see Table 4-7) to enable us to project smolt survival with our equation. These projections indicate that the Rio Vista flow salmon standards alone would yield essentially no benefit to smolt survival (Table 4-7). The striped bass outflow standards for May and June afford better protection with a projected index of survival of 0.05 in dry years to 0.35 in wet years (Table 4-7). The existing operational standards provide for closing the Delta Cross channel for a Table

Table 4-6. Estimates of annual Delta smolt survival derived from monthly survival indices times the percent of the annual number of smolts migrating past Chipps Island that month.1/

Estimated Survival Indices
(Percent migrating past Chipps Island)

Year	A	M	J	Estimate of Annual Survival
1978	1.00 (27)	.82 (40)	.11 (33)	.63
1979	.46 (19)	.36 (52)	.09 (29)	.30
1980	.85 (14)	.47 (34)	.42 (52)	.49
1981	.48 (34)	.21 (50)	.02 (16)	.27
1982	1.00 (18)	1.00 (49)	.98 (33)	.99
1983	1.00 (19)	1.00 (49)	1.00 (32)	1.00
1984	.58 (11)	.32 (66)	.22 (23)	.33
1985	.10 (26)	.18 (63)	.18 (10)	.16
1986	1.00 (37)	.27 (55)	.09 (08)	.53

1/ Monthly survival is estimated from monthly flows at Rio Vista using our linear relationship between survival and flow (y=0.000056x-0.258x where y=survival and x=mean monthly Rio Vista flow). Data used to derive the equation was from 1969-1971 and 1978 to 1981.

Table 4-7. Flow standards for salmon and striped bass and projected smolt survival through the Sacramento Delta under the existing 1978 Delta plan.

Salmon (March 16 - June 30)

Year Type	Rio Vista Flow	Projected Salmon Survival
Wet	5000	.02
Above Normal	3000	0
Below Normal	3000	0
Dry/Critical	2000	0

Striped Bass

(May 6-31)

Year Type	Delta Outflow1/	Estimated Rio Vista Flow	Projected Salmon Survival
Wet	14000	10945	.35
Above Normal	14000	10945	.35
Below Normal	11400	9504	.27
Subnormal Snowmelt	6500	6788	.12
Dry	4300	5569	.05
Dry/Critical	3300	5015	.02

(June)

Year Type	Delta Outflow2/	Estimated Rio Vista Flow	Projected Salmon Survival
Wet	14000	10763	.34
Above Normal	10700	9080	.25
Below Normal	9500	8468	.22
Subnormal Snowmelt	5400	6378	.10
Dry	3600	5460	.05
Dry/Critical	3100	5204	.03

1/ Delta outflow in May was converted to Rio Vista flow in May by using the equation $y=3187.1+.55412x$ where x=Delta outflow and y=Rio Vista flow. The equation was developed by regressing Delta outflow to Rio Vista flow from 1956-1985 ($r=0.99$).

2/ Delta outlfow in June was converted to Rio Vista flow in June using the same method as for May, with the equation $y=3623.7+.50998x$ and $r=.97$.

portion of the time from April through May when the Delta outflow index is greater than 12,000 cfs but we have not attempted to estimate that added benefit.

In an attempt to index the presumed changes in smolt survival through the Delta over time for the various water year types, we used flows from the Department of Water Resources (1987) and their 1987 Bay/Delta Hearing Exhibits 28 to 30 to project Delta inflow for the unimpaired, 1920, 1940, and 1990 levels of development. These exhibits simulate flows from the Sacramento Basin rather than Rio Vista flows so we regressed smolt survival on Sacramento River flow at I Street. Smolt survival peaked at an I Street flow of 31,000 cfs. The survival:flow relationship probably yields lower survivals per unit flow than occurred historically because fish were not diverted at the Delta cross channel before 1950. The diversions of smolts through the cross channel lessens survival as shown previously. The resulting survival estimates should provide comparisons of survival at various flow regimes.

The results indicate that Delta smolt survival through the Sacramento Delta has decreased with lesser inflow to the Delta caused by water development in the Sacramento Valley (Table 4-8). The greatest differences, as expected, were seen in the dry and critical years. The projected decrease in inflow to the Delta between unimpaired flows and that of the 1990 level of development was reflected in an average drop in Delta smolt survival of about 40% while the projected difference in survival between 1940 and 1990 averaged 28%. These estimated decreases in survival are an

Table 4-8. Average estimated Delta fall-run smolt survival indices by water year type at different levels of development; unimpaired (no development) at 1920, 1940, and 1990 levels of development.1/

Water Year Types	(Sample Size)	Unimpaired No Development	1920 level of Development	1940 level of Development	1990 level of Development
Wet	(19)	.97	.92	.91	.83
Above Normal	(10)	.91	.85	.83	.61
Below Normal	(10)	.84	.69	.66	.41
Dry	(10)	.76	.57	.55	.33
Critical	(8)	.33	.17	.21	.12
Mean		.76	.64	.63	.46

1/ Annual survivals were estimated by weighting monthly survival indices by the average percent from 1978 to 1986 of total outmigrants going to sea (22% in April, 51% in May and 27% in June). Monthly survival indices were estimated from monthly flows using our linear relationship between salmon survival and flow at "I" Street where y = 0.00005x - 0.465 when y = survival and x = mean monthly "I" street flow. Data from 1969-71 and 1978-81 was used to derive the equation. Monthly flows for the four different levels of development was obtained from California Department of Water Resources (Bob Zettlemoyer, pers. comm. and DWR Board exhibits 28-30).

approximation of the minimum impact of water development in the Sacramento Basin on salmon production as they only include the effects of reduced flows and do not correct for the fact that there was no Cross channel prior to 1950 which should have improved survival per unit flow in those earlier years in the Delta.

Summary

The above information on smolt migration through the Sacramento Delta indicates that migrating chinook smolt survival is improved when:

1. Flow in the Sacramento River is increased, with maximum survival observed when flows at Rio Vista are at or above about 20,000 to 30,000 cfs.
2. Temperatures are below 66°F.
3. The diversion of smolts off the Sacramento River via the cross channel are eliminated. Closing the Delta cross channel is beneficial to survival, particularly at low flows when temperatures are acceptable.
4. Flow is seaward in the lower San Joaquin River at Jersey Point (i.e., no reverse flows).

It is important to understand that chinook salmon smolt survival through the Delta is improved by the combination of increased flow and decreased diversions and temperatures. Increasing Sacramento River flow at Rio Vista will decrease the negative affect of diversions but may not lower water temperature sufficiently to help survival if ambient air temperature is high. In 1987 the closing of the Delta cross channel under very low flows (~5,200 cfs at Rio Vista) provided a 60% increase in smolt survival with water temperatures of 66°F. We know that when the percentage of the Sacramento River diverted is high (>60% at Walnut Grove) and when temperatures are high (>68°F) we have very poor survival. Fish that are diverted off the Sacramento are helped by preventing reverse flows in the lower San Joaquin but it is far better to keep them out of the Central Delta.

The survival:flow relationship and other evidence on diversion and temperature effects indicates that the present salmon flow standards in the 1978 Delta Plan are indadequate and would provide very low survival for smolts in the Delta when the Cross channel gates were open and or when temperatures were over 68°F. Meeting the striped bass flow and operational standards in the 1978 Plan would provide some increase in survival. Water development in the Sacramento Valley has reduced flow to the Delta during fall-run smolt migration. These reductions combined with the present Delta diversions off the Sacramento River have been enough to reduce average survival by an average of at least 27% since 1940.

Smolt Survival in the San Joaquin River Delta

Smolt migrating through the southern Delta from upstream tributaries often face harsh environmental conditions to include high temperatures, low flows and high diversion rates. During most spring outmigration periods, project exports in the south Delta off Old River are greater than the flow in the San Joaquin River at Vernalis. Between 1970 and 1984, flows exceeded exports in the San Joaquin River in only four years (1978, 1980, 1982 and 1983). If salmon smolts go with the diverted water as appears to be the case in the Sacramento Delta at Walnut Grove, they are exposed to the CVP/SWP diversion facilities. Other interagency studies indicate that such exposure results in increased mortalities. Negative aspects of smolt exposure to the south Delta Project diversions include: predation at the Project fish screens and in Clifton Court Forebay, louver screen inefficiencies, temperature stress and handling losses in the fish facility salvage proces. A review of the fish screen salvage and associated predation losses is provided by the Department of Fish and Game in Exhibit 17 entitled "Entrainment Losses".

Increased flow in the San Joaquin River at Vernalis decreases the percentage of water diverted down Old River and probably the numbers of salmon that enter Old River. Higher flows in the San Joaquin River in May decrease water temperature (CDFG Exhibit 15). Temperatures in the southern Delta are usually higher than other parts of the Delta (Table 4-4).

Various evidence indicates that increased flows to the San Joaquin Delta during fall-run smolt migration yield greater adult production. Such a relationship should, in part, reflect the lessening of fish being diverted to the pumping plants and lower Delta water temperatures. Both conditions should increase smolt survival through the San Joaquin Delta.

We have observed that the greater flows in the San Joaquin River during the April through June smolt migration results in a greater number of returning adult spawners two and one-half years later (Figure 4-7 and Appendix 25). Adult spawners and chinook in the ocean catch are primarily three years old, hence, the 2-1/2 year lag (Reisenbichler, 1986; Appendix 13). A plot of both escapement and flow during smolt migration over time is another way to show that the three increases in spawner levels seen in the San Joaquin since 1958 have been associated with springs of high runoff (Figure 4-8).

Additional relationships of this type are found in Department of Fish and Game Exhibit 15 describing the needs of salmon in the upper San Joaquin drainage. Evidence in that Exhibit indicates Tuolumne River spawner escapement per unit of flow during spring smolt migration has decreased over time. This decrease in salmon production reflects increased storage in that drainage, the increased impacts of both the CVP and the SWP diversions in the Delta, and of decreases in flow on the main San Joaquin by the CVP (Friant Dam).

Reisenbichler (1986) who modeled Central Valley fall-run chinook populations to describe the influence of environmental change and increased fishing on spawner-recruit relations was able to document a negative relationship between San Joaquin fall-run chinook survival (after adjusting for spawner density) and CVP/SWP exports. Survival from egg to adult in years when exports exceeded the flow in the San Joaquin averaged about 74%, less than in other years (Figure 4-9).

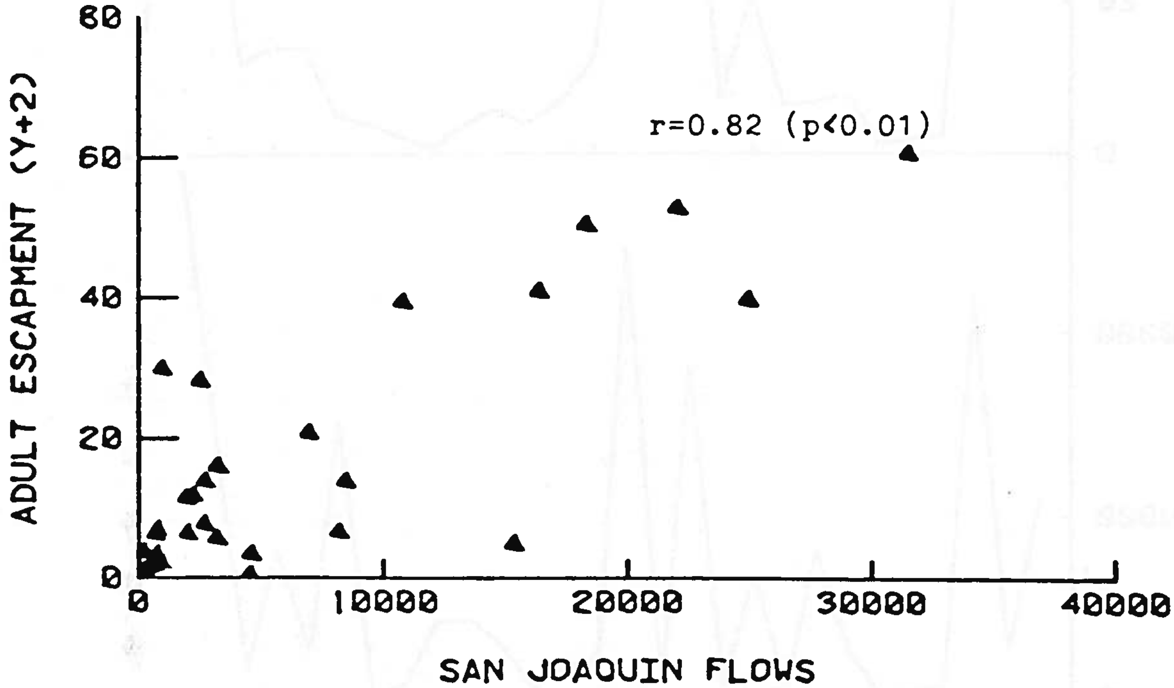

Figure 4-7. Spring flows (mean of April through June) in the San Joaquin River at Vernalis (1956-1984) experienced by the juvenile outmigrants versus the resulting adult escapement in the San Joaquin 2-1/2 years later.

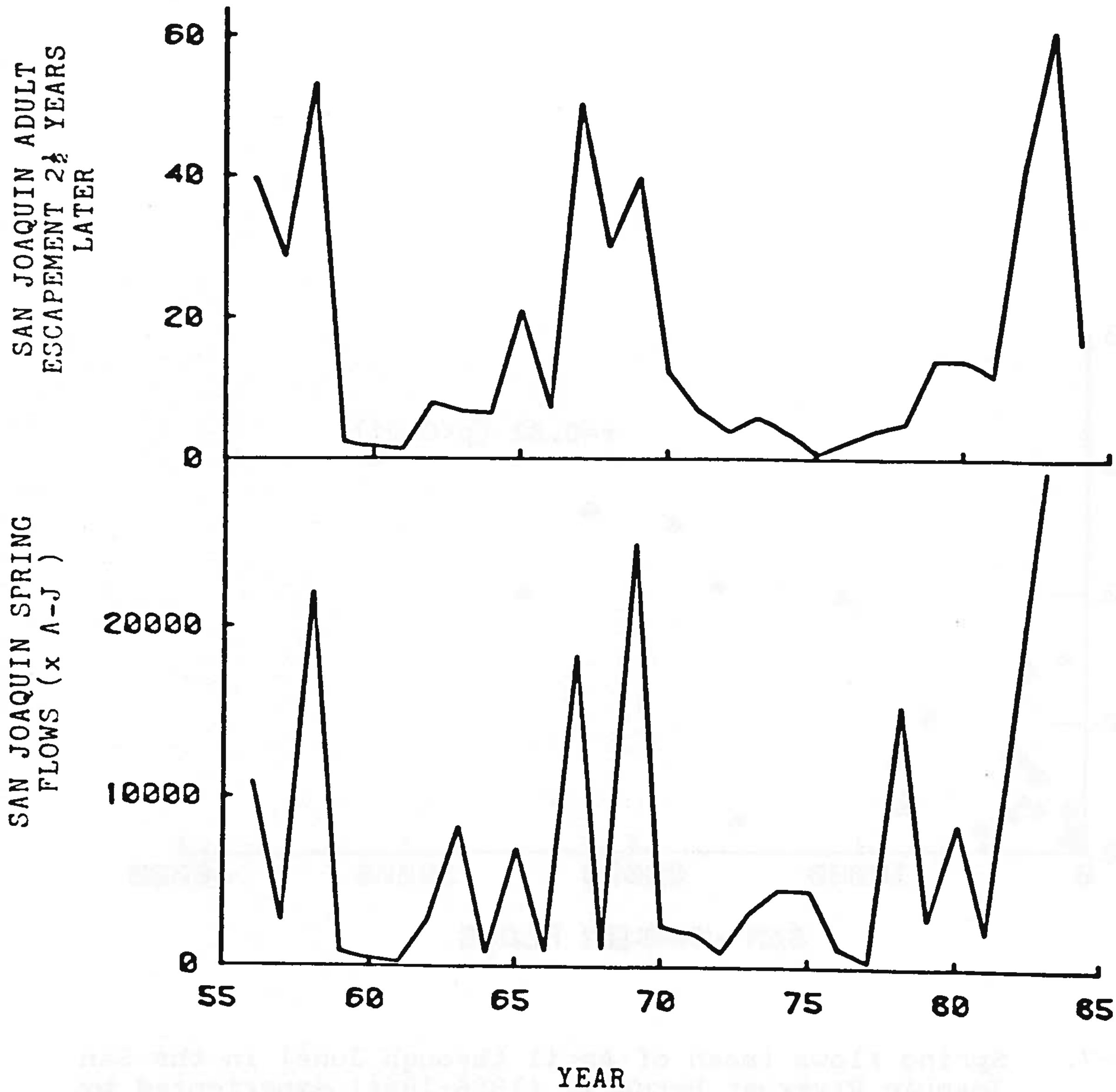

Figure 4-8. Spring flows (mean April through June) experienced by the juvenile outmigrants in 1956 to 1984 and the resulting San Joaquin adult escapement in 1958-1986 (two year lag).

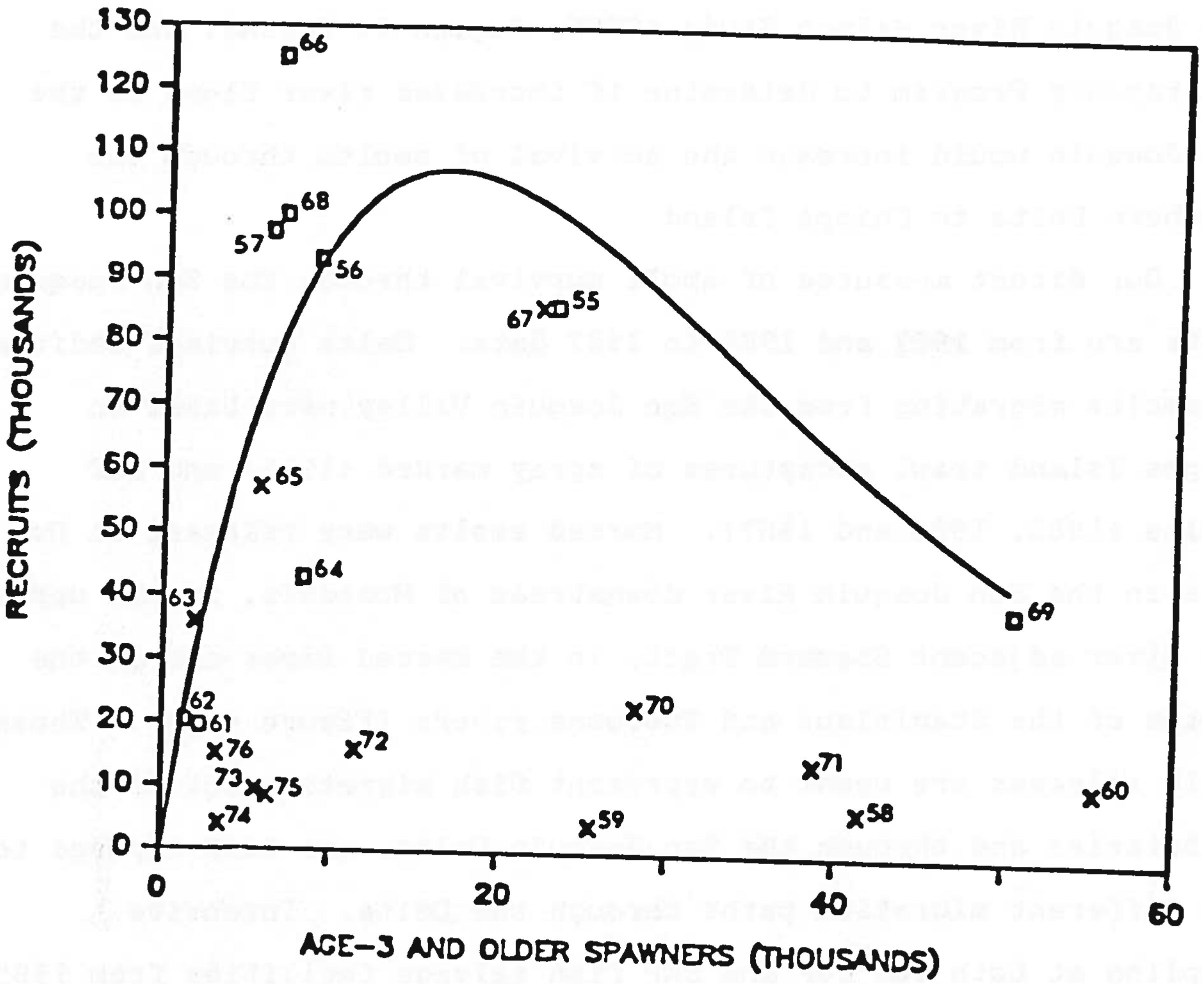

Figure 4-9. Spawner-recruit relation for fall chinook salmon from the San Joaquin River, 1955-76 year classes. Numbers associated with a square identify year classes used to derive the relation. Other year classes, except for 1972, were not used because they were affected by water withdrawals that exceeded the downstream flow of the river. The 1972 year class was rejected as an outlier (from Reisenbichler, 1986).

Based on the above evidence, studies were initiated by the San Joaquin River Salmon Study (CDFG, Region 4, Fresno) and the Interagency Program to determine if increased river flows in the San Joaquin would increase the survival of smolts through the southern Delta to Chipps Island.

Our direct measures of smolt survival through the San Joaquin Delta are from 1982 and 1985 to 1987 data. Delta survival indices of smolts migrating from the San Joaquin Valley were based on Chipps Island trawl recaptures of spray marked (1985) and CWT smolts (1982, 1986 and 1987). Marked smolts were released at Dos Reis in the San Joaquin River downstream of Mossdale, in the upper Old River adjacent Steward Tract, in the Merced River and at the mouths of the Stanislaus and Tuolumne rivers (Figure 4-10). These smolt releases are meant to represent fish migrating out of the tributaries and through the San Joaquin Delta, and fish exposed to two different migration paths through the Delta. Intensive sampling at both the CVP and SWP fish salvage facilities from 1985 to 1987 provided an estimate of the total number of marked fish by release group that had entered the facility and were salvaged by expanding the number of CWT smolts collected using the fraction of time sampled. Survival indices, S_T, for each tagged smolt release group were calculated from tag recoveries in the Chipps Island trawl. Release conditions, fish salvage facility recoveries and survival information is provided in Table 4-9 and Appendices 24a to 24e.

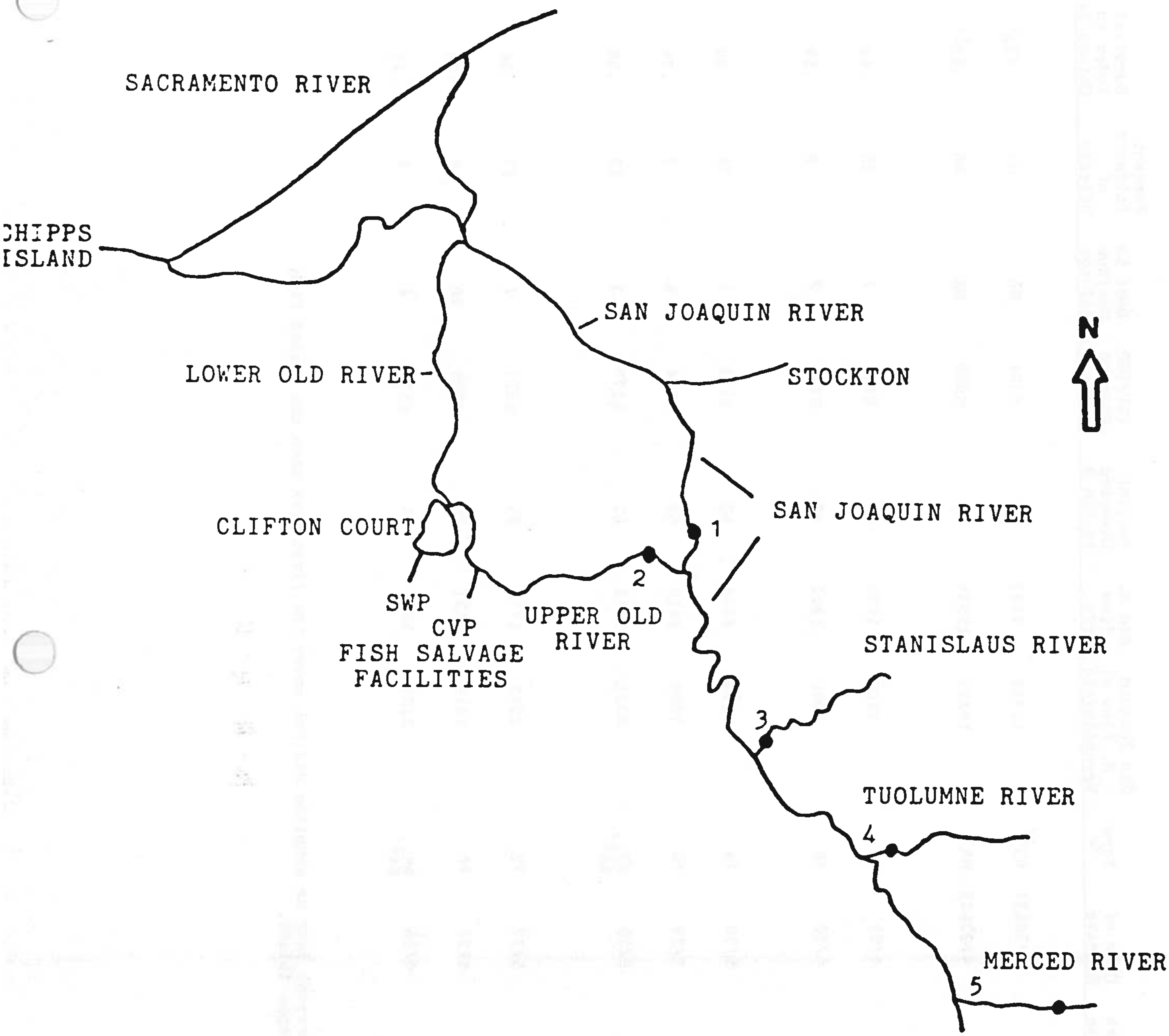

Figure 4-10. Schematic of the southern Delta and San Joaquin River Tributaries showing marked salmon release sites, CVP/SWP salvage facilities (fish screens) and Chipps Island in the Sacramento-San Joaquin Delta. Releases sites are: 1. San Joaquin River at Dos Reis, 2. Upper Old River 3. Lower Stanislaus River, 4. Lower Tuolumne River and 5. Merced River at Snelling.

Table 4-9. Relative Survival (S_T) of Marked Juvenile Chinook Salmon Released in South Delta in 1985, 1986 and 1987.

Release Site	Number Released	Mean Fork Length/mm	Date of Release	Temp. °F	San Joaquin R. flow at Vernalis/cfs	Old R. flow cfs	Percent Diverted to Old R.	CVP/SWP Exports cfs	Days to Maximum Salvage	Percent Salvaged of Release	Survival Index to Chipps Is.	Days Migration to Chipps Is.
1982												
Merced River at Snelling	49217	68	4/20&21	65 2/	12339	7403	60	5304	NA	NA	.62 1/	
San Joaquin River	48227	67	4/22&23	NA	19233	11539	60	5598	NA	NA	.60 1/	
1985												
Upper Old River (dyed)	150048	79	4/29	70	2400	1920	80	6215	2	25	.62	3
San Joaquin River (dyed)	149968	79	4/30	70	2400	1920	80	6215	7	3	.59	10
1986												
Upper Old River (CWT)	107215	96	5/30	70	7000	4410	63	6214	1	74	.20	3
San Joaquin River (CWT)	91040	96	5/29	70	7000	4410	63	6214	6	3	.34	4
Lower Stanislaus River (CWT)	110175	89	5/29	63 64 2/	8731	5413	62	6177	3	13	.58	9
1987												
Upper Old River (CWT)	90952	82	5/27	72	2092	1778	85	6527	1	27	.16	3
San Joaquin River (CWT)	92721	79	4/27	70	1819	1637	90	6395	10	8	.82	10
Lower Tuolumne River (CWT)	93477	82	4/16	64 64 2/	2157	1833	85	6573	4	9	.17	8

1/ This is considered a minimum survival rate as sampling did not cover the first week when the marked fish were likely to be passing by Chipps Island.

2/ Temperature at Vernalis.

The survival indices of tagged smolts between upstream release points in the San Joaquin drainage to Chipps Island were over three times greater with higher San Joaquin River flows in 1982 (0.62) and 1986 (0.58) than with low flows in 1987 (0.17) (Table 4-9). These smolts, released in the Merced in 1982 and at the mouth of the Stanislaus in 1986, had San Joaquin River flows ranging from about 8,700 to 12,000 cfs at Vernalis while those released at the mouth of the Tuolumne in 1987 only had about 2,200 cfs. The survival index in 1982 is considered minimal due to less trawling effort than in 1986 and 1987. Both 1982 and 1986 flows in the San Joaquin were greater than the Project export levels and resulted in greater survival.

The percentage of flow diverted off the San Joaquin into upper Old River (Appendix 21) increased from 60% during the high flows of 1982 to 85% during the low flow of 1987 (Table 4-9). The 1982 smolt release at Dos Reis in the San Joaquin River below the upper Old River junction survived at essentially the same rate (0.60) as those released in the Merced River indicating very little mortality occurred between the Merced and Dos Reis. Temperatures were relatively similar during 1986 and 1987 but cooler in 1982 which could have provided some advantage. The fraction of these "above Delta" releases that were salvaged at the facilities (13% in 1986 and 9% in 1987, Table 4-9) sheds uncertainty as to what fraction of these fish were diverted off the San Joaquin and where and by what cause mortalities occurred. Additional data f'om tagged smolts released immediately above and below the junction with upper Old River are needed. Nevertheless, these available data suggest that higher flows and decreased diversions off the San Joaquin in the southern Delta improve smolt survival during downstream migration through the Delta.

The survival of marked salmon released in upper Old River and in the San Joaquin at Dos Reis from 1985 to 1987 suggest that it is generally advantageous for smolts to remain in the San Joaquin River. Survivals of the Dos Reis fish (released below the upper Old River diversion point) was at least 40% greater than those released in upper Old River in 1986 and 1987, and similar in 1985 (Table 4-9). This suggests fish diverted off the San Joaquin down upper Old River to the Project diversions would generally suffer greater moralities than those not diverted. The results from 1985 suggest in that year it did not make any difference.

The survival of salmon released at Dos Reis to Chipps Island while variable (0.34 to 0.82) did not appear affected by the variations in flow. Temperatures were considered adverse (70°F) but we could not evaluate their impact. The survival index (0.82) of the Dos Reis release in 1987 was surprisingly high at a very low San Joaquin River flow and high temperature.

The smolts released at Dos Reis arrived at Chipps Island in a shorter time in 1986 (4 days) than in 1985 or 1987 (10 days) suggesting that the higher flows in 1986 (7,000 versus 2,000 in 1985 and 1987) increased their rate of migration, which should be beneficial to survival.

As expected, in all three years a greater fraction of smolts from upper Old River release group were salvaged at the facilities than from the San Joaquin release (Table 4-9). This reflects the direct route to the salvage facilities of fish from the upper Old River release. More of the upper Old River release were seen at the CVP facility (Appendix 24). Smolts from the San Joquin release were seen at the facilities in relatively small numbers (3 to 8% of the number released) (Table 4-9). Those that were salvaged from the San Joaquin release were primarily at the State salvage facility (SWP) and had arrived there about five to six days after those from the upper Old River group (Appendix 24a-e). This appears to reflect their longer migration route down the San Joaquin and then to the south via lower Old River reverse flows (Table 4-9). Smolts migrating down the San Joaquin may not be highly vulnerable to reverse flows in the lower Old and Middle Rivers. This is suggested by the low percentage salvaged and relatively high survival indices for the Dos Reis release in 1985 and 1987 when flows were low and reverse flows were present in the lower San Joaquin River (Table 4-3). Appendix 24a-3 provides detailed daily recoveries of each release group by salvage facility.

Summary

The available data indicates that the survival of fall-run smolts migrating from the San Joaquin drainage through the Delta increases with flow. Smolt survival and resulting adult production is most favorable when flow at Vernalis is greater than the amount of Central Valley and State Water Project diversions.

Smolt survival generally is better for fish that avoid being diverted off the San Joaquin into upper Old River than for those that are diverted toward the pumps suggesting that diversion is a key mechanism affecting smolt survival. Increased flow in the San Joaquin lessens the percentage of water diverted down Old River and probably the numbers of fish that enter Old River.

Increase flow also appears to increase migration rate. Smolt migration rate over doubled as inflow increased from 2,k000 to 7,000 cfs. Temperatures in the San Joaquin Delta channels are often considered adverse to migrating chinook smolts (often 70°F or higher). Tagged smolts that are released in the San Joaquin below the upper Old River junction were not salvaged at the fish facilities project in high numbers suggesting that they may in some way avoid being carried with reverse flows in lower Old and Middle rivers to the pumping plants.

While the above conclusions appear logical and biologically sound, there is a need for continued mark/recapture studies in the San Joaquin Delta to provide a more extensive data base with which to draw conclusions as to the factors and behavior characteristics influencing the survival of fall-run smolts throughout that system.

San Francisco Bay Smolt Survival

In 1984 CWT post-smolts were released at both Port Chicago and the Golden Gate Bridge to achieve an estimate survival through the Bay using the method based on tag recoveries from the ocean fishery. Similar releases of CWT smolts were made in 1985 and 1986 but recovery data will not be available until 1988 and 1989.

The post-smolt (~110 mm) release in July of 1984 at a Delta outflow of 10,000 cfs yielded an estimate of 81% survival through the Bay (Appendix 13).

We also estimated smolt survival (S_T) through the Bay (from 1984 to 1986) using tag recoveries from daily midwater trawling at the Golden Gate of CWT smolts released in Suisun Bay. This effort yielded survival indices that were extremely variable, ranging from 0.75 to 2.39 at a relatively constant Delta outflow of about 10,000 cfs. We have not been able to document the exact reasons for the wide range in these survival indices as measured by trawling at the Golden Gate but believe it may be due to the extreme tidal fluctuations at the Gate which may increase sampling bias and variability. However it is evident that we cannot evaluate the potential importance of Delta outflow on smolt survival in the Bay with the S_T data.

<u>Summary</u>

Our available data is too sparse to draw any conclusions on the influence of Delta outflow on smolt survival in the Bay. The 1984 data indicates survival was relatively high for a rather low Delta outflow index of 10,000 cfs. Ocean tag recovery data that will be available from the 1987 to 1989 fishing season from CWT smolt releases in 1985 and 1986 will yield two more estimates of smolt survival through the Bay at outflows of 10,000 cfs.

the Bay using the method based on tag recoveries from the ocean fishery. Similar releases of CWT smolts were made in 1985 and 1986 but recovery data will not be available until 1988 and 1989.

The post-smolt (10 cm) release in July of 1984 at a Delta outflow of 10,000 cfs yielded an estimate of 61% survival through the Bay (Appendix 13).

We also estimated smolt survival (S_2) through the Bay (from 1984 to 1986) using tag recoveries from daily midwater trawling at the Golden Gate of CWT smolts releases in Suisun Bay. This effort yielded survival indices that were extremely variable, ranging from 0.75 to 3.30 at a relatively constant Delta outflow of about 10,000 cfs. We have not been able to document the exact reasons for the wide range in these survival indices as measured by trawling at the Golden Gate but believe it may be due to the extreme tidal fluctuations at the Gate which may increase sampling bias and variability. However it is evident that we cannot evaluate the potential importance of Delta outflow on smolt survival in the Bay with the S_2 data.

Summary

Our available data is too sparse to draw any conclusions on the influence of Delta outflow on smolt survival in the Bay. The 1984 data indicates survival was relatively high for a rather low Delta outflow index of 10,000 cfs. Ocean tag recovery data that will be available from the 1987 to 1989 fishing season from CWT smolt releases in 1985 and 1986 will yield two more estimates of smolt survival through the Bay at outflows of 10,000 cfs.

Section 5

INFLUENCE OF FLOWS DURING SMOLT OUTMIGRATION ON ADULT PRODUCTION

Our evidence indicates that fall-run smolts experience greater mortality in the Delta with decreasing flows, higher diversions and higher temperatures. Junge (1970) concluded that nonselective smolt kills as caused by diversion or high temperatures that occur in the Delta, would result in direct and proportional decreases in adult salmon production. Conversely, an increase in survival and in the number of smolts entering the sea should result in greater adult numbers. We have observed that smolt survival through the Delta and the numbers of smolts leaving the Delta are positively correlated with flow during the smolt migration period (Figures 4-1, 4-2 and 3-6). Hence, we would expect that increased flows during outmigration will yield more adults.

Again, flow can be used as an "index" parameter to reflect overall Delta conditions during smolt migration. Flow levels also reflect temperature and diversion levels since both temperature and diversions are well correlated with flow.

Correlation analyses have been used in an attempt to evaluate the importance of flow to the adult abundance of fall run chinook. Central Valley chinook have historically returned to spawn at ages ranging from primarily 2 to 5 years. Thus several year classes contribute to the spawner escapement in any one year.

This causes difficulty when attempting to quantify accurately the escapement of a given year class since measures of salmon age composition from Central Valley stocks are limited. In recent years, returns of known age (coded wire tagged) spawners indicate that most are three years old. Hence, we used a 2-1/2 year lag between the time of smolt migration and escapement but the approach still yields imprecision in the adult escapement estimates.

Correlations between spawner escapement (1958 to 1986) in the three San Joaquin River tributaries and mean April through June flow at Vernalis (1956 to 1984) 2-1/2 years earlier yielded a positive relationship (Figure 4-7).

We also found that total Central Valley adult spawner numbers (1960-1986) were more roughly related to the May Delta outflow experienced by the smolts 2-1/2 years earlier (1958 to 1984) (Figure 5-1, Appendix 25).

Earlier work by Dettman et al. (1987) using two-year moving averages of total spawner escapement, Sacramento River flow, and Delta outflow found a positive correlation between upper Sacramento River salmon escapement and spring flows from 1952-1967 but no relationship for the 1968-81 period. The use of two-year moving average is designed to overcome, in part, the problem of several year classes contributing to spawner escapement in any one year. A variety of changes occurred about 1967 which increased the factors that influenced salmon spawner abundance and this possibly lessened the correlation between flow and escapement.

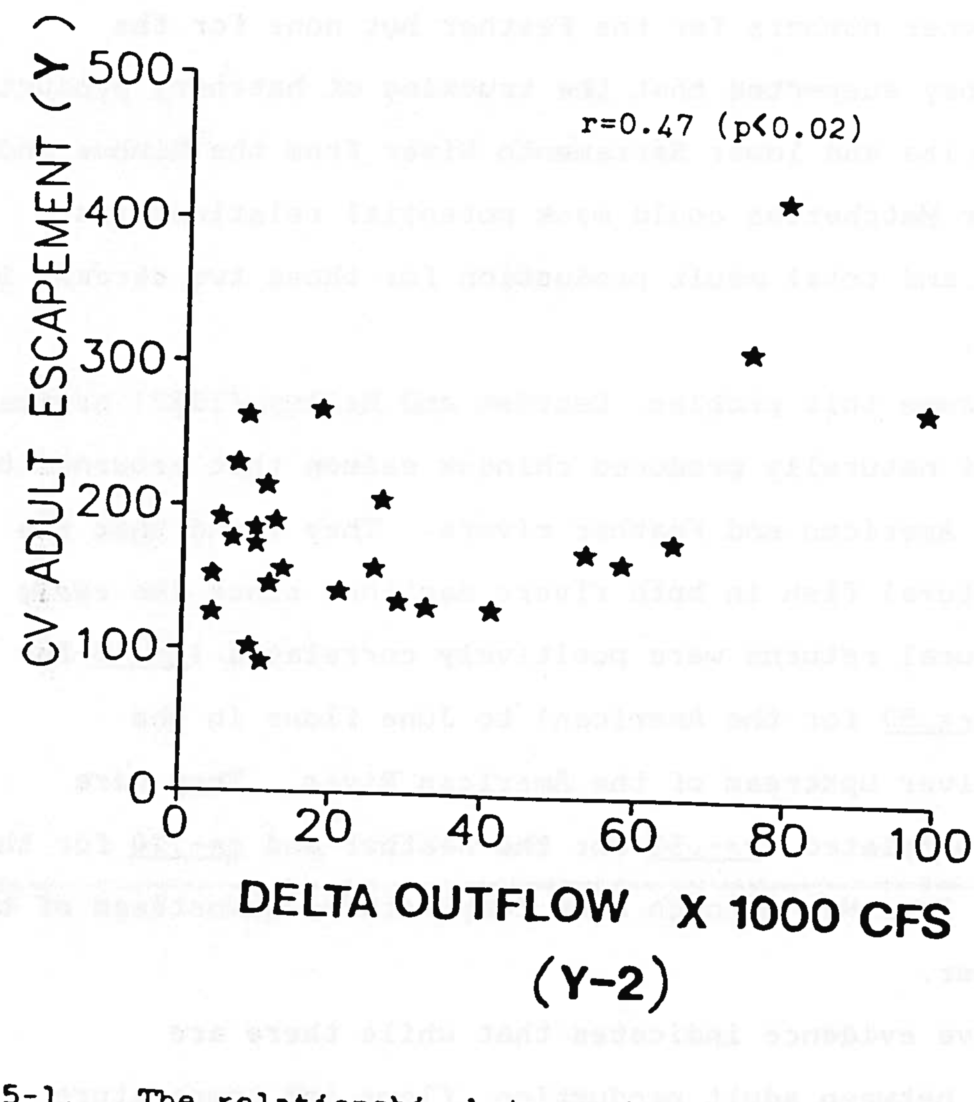

Figure 5-1. The relationship between Central Valley adult escapement in 1960-1986 versus May Delta outflow experienced 2-1/2 years earlier as juvenile outmigrants.

These include the closing of Red Bluff Diversion Dam, increase in Delta diversions by initiation of State Water Project exports, the transfer of Trinity River water to the Sacramento basin, and increased trucking of hatchery production around the Delta.

Dettman (et al. 1987) found a relationship between spring flow and spawner numbers for the Feather but none for the American. They suspected that the trucking of hatchery production around the Delta and lower Sacramento River from the Nimbus and Feather River Hatcheries could mask potential relationships between flow and total adult production for those two streams in recent years.

To overcome this problem, Dettman and Kelley (1987) estimated the number of naturally produced chinook salmon that returned to spawn in the American and Feather rivers. They found that the number of natural fish in both rivers declined since the early 1970's. Natural returns were positively correlated (<u>r=.48</u> for the Feather and <u>r=.57</u> for the American) to June flows in the Sacramento River upstream of the American River. They were negatively correlated (<u>r=-.56</u> for the Feather and <u>r=-.70</u> for the American) to late May through June temperatures downstream of the American River.

The above evidence indicates that while there are correlations between adult production, flows and temperature, it is very difficult to predict the number of adult returns based only on flow or temperature during smolt migration. This is not unexpected since Central Valley salmon production is influenced by a variety of additional factors both in fresh water and in the ocean. A major problem appears to be the difficulty in estimating the contribution to spawner escapement of hatchery fish that were not exposed to flow and temperature in the Delta and Lower Sacramento River. In addition, there is variation and error in measuring spawner levels and the annual age composition of chinook escapement.

Reisenbichler (1986) found that bias due to the lack of age composition was a greater problem for the estimates of California chinook spawner numbers by brood year than that caused by sampling error in spawning counts.

Summary

The above analyses indicates that there are only fair correlations between the spawner returns of fall-run chinook salmon and flow and temperature experienced by outmigrant smolts. However, considering that many factors limit adult salmon production, the correlations are relatively good and indicate that flow, temperature (and diversion) still are important. The relationship appears obscured in part by the major contribution to adult salmon stocks of hatchery smolts that are not exposed to the flows being evaluated. The relationships are potentially further damaged by inaccurate spawner escapement estimates (by year class) due to the lack of age composition data. Even though it is difficult to quantify the expected benefits of increased flows and decreased diversions and temperatures to adult salmon production, it would always appear beneficial to maximize the number of juvenile outmigrants. This would result in: (1) the maximum production of salmon when the ocean environment is "good", and (2) more salmon than would be available otherwise when the ocean environment is "poor".

Section 6

FRY REARING

The following information on chinook rearing in the Estuary is based on our annual seine survey data and our coded wire half tag fry recoveries. A description of the methods used is provided in Appendix 26.

Timing, Distribution and Abundance

Fall-run chinook fry generally emerge from the gravel of upstream spawning areas from December to February. Most probably rear to smolthood in rearing areas above the Delta but some migrate to the estuary and their abundance in the Delta is usually highest in February or March (Appendix 27). Chinook fry that move into the Estuary rear there for up to several months prior to smolting (Kjelson et al. 1982).

In the Estuary the greatest concentrations of fry were observed in the north Delta and the least in San Francisco Bay (Table 6-1). Fry in the north Delta originate in the Sacramento drainage, while in the central Delta, fry from both the San Joaquin and Sacramento basins are present. This fact was confirmed when tagged (CW1/2T) fry released in the north Delta were recovered in the Central Delta and at the CVP/SWP fish screen facilities (Appendices 28 and 29).

Table 6-1. Average catch per seine haul of Chinook salmon fry in the Bay-Delta Estuary and Lower Sacramento River, January through April, 1977 through 1986.

Year	Northern Delta	Central Delta	San Francisco Bay	Lower Sacramento
1986	30	10	2	27
1985	10	3	0	2
1984	11	4	0	9
1983	39	9	2	30
1982	21	4	1	23
1981	12	2	0.5	23
1980	17	2	4	NS
1979	33	6	NS	NS
1978	16	NS	NS	NS
1977	.37	NS	NS	NS
n =	12	9	8[1/]	7

1/ These eight stations are circled on Figure 18-1.

n = The number of seining stations in respective areas of the Delta, Sacramento River and San Francisco Bay.

NS = Not sampled.

Flow Influence on Fry Abundance and Distribution

Our seine data indicates that estuarine chinook fry abundance is increased and distribution more widespread when river flows are high (Figure 6-1). Fry are restricted to the Delta in lower runoff years but are found further downstream into San Francisco Bay in wetter years. The high runoff during February of 1986 resulted in the highest monthly (February) fry seine index (6 fish/haul) observed in San Francisco Bay (Appendix 27).

We found a significant relation between relative fry abundance in the northern Delta and mean daily Sacramento River flow at "I Street" in February (Figure 6-2). The San Francisco Bay fry index also was correlated to the mean Delta outflow in February (Figure 6-3).

Several mechanisms may explain why more salmon fry are seen in the Delta and in the Bay in years of high runoff: a) high flow may physically remove them from upstream rearing areas (Kjelson et al. 1982), and b) increased turbidity may give them a cue to initiate a downstream migration.

A total of 12 of the CW1/2T fry released below Red Bluff Diversion Dam or at the nearby Tehama Colusa Fish Facility since 1980 were recovered as fry in the estuarine seine surveys. This is a small number compared to the numerous recoveries from north Delta releases during the same period (Appendix 28). This indicates that most fry produced in the upper Sacramento River, may rear above the Delta. Possibly most of the fry seen in the Delta are of American or Feather/Yuba River origin as those streams are so much closer to the Delta.

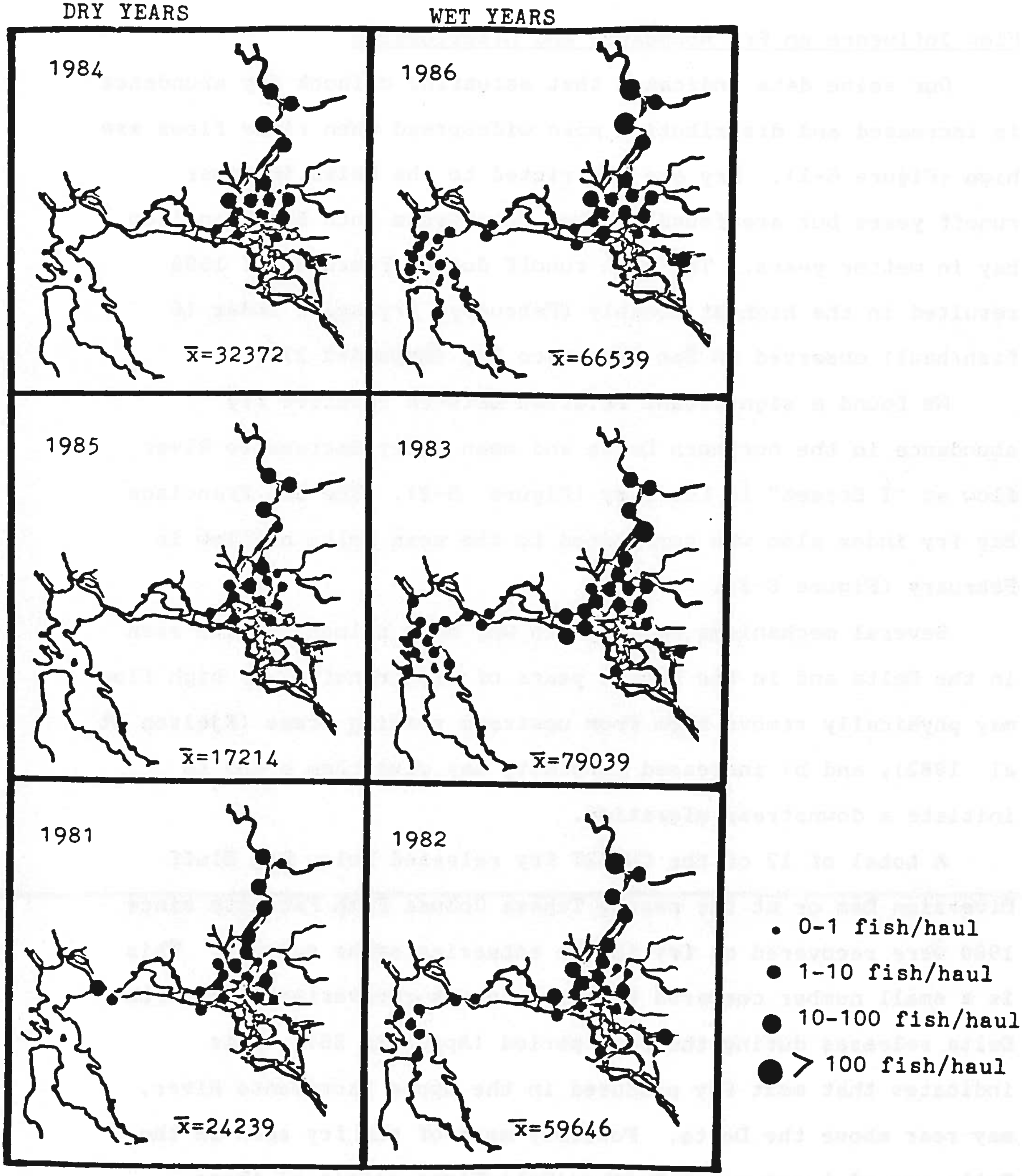

Figure 6-1. Abundance and distrubution, from January through April, 1981 to 1986, of chinook salmon fry through-out the Delta and Bay in wet and dry years, including mean daily February flows at "I" Street in Sacramento. The size of the circles represent relative abundance estimates.

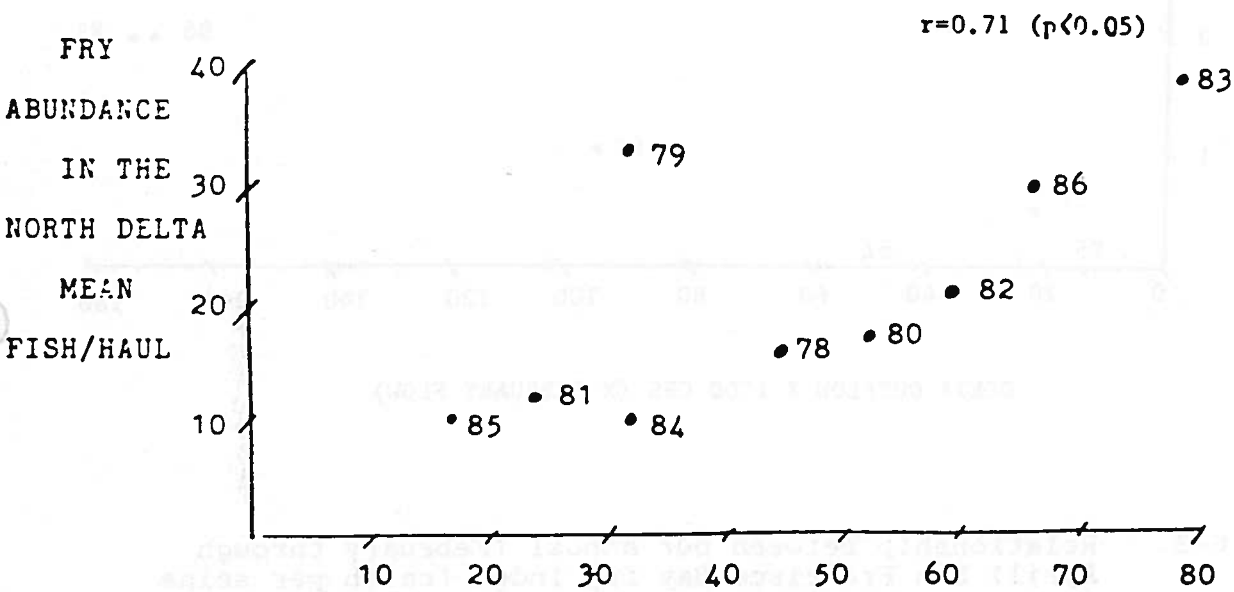

Figure 6-2. Relationship between our index of fry abundance (catch per seine haul) in the North Delta (January through April) and mean daily February flow at "I Street" in Sacramento.

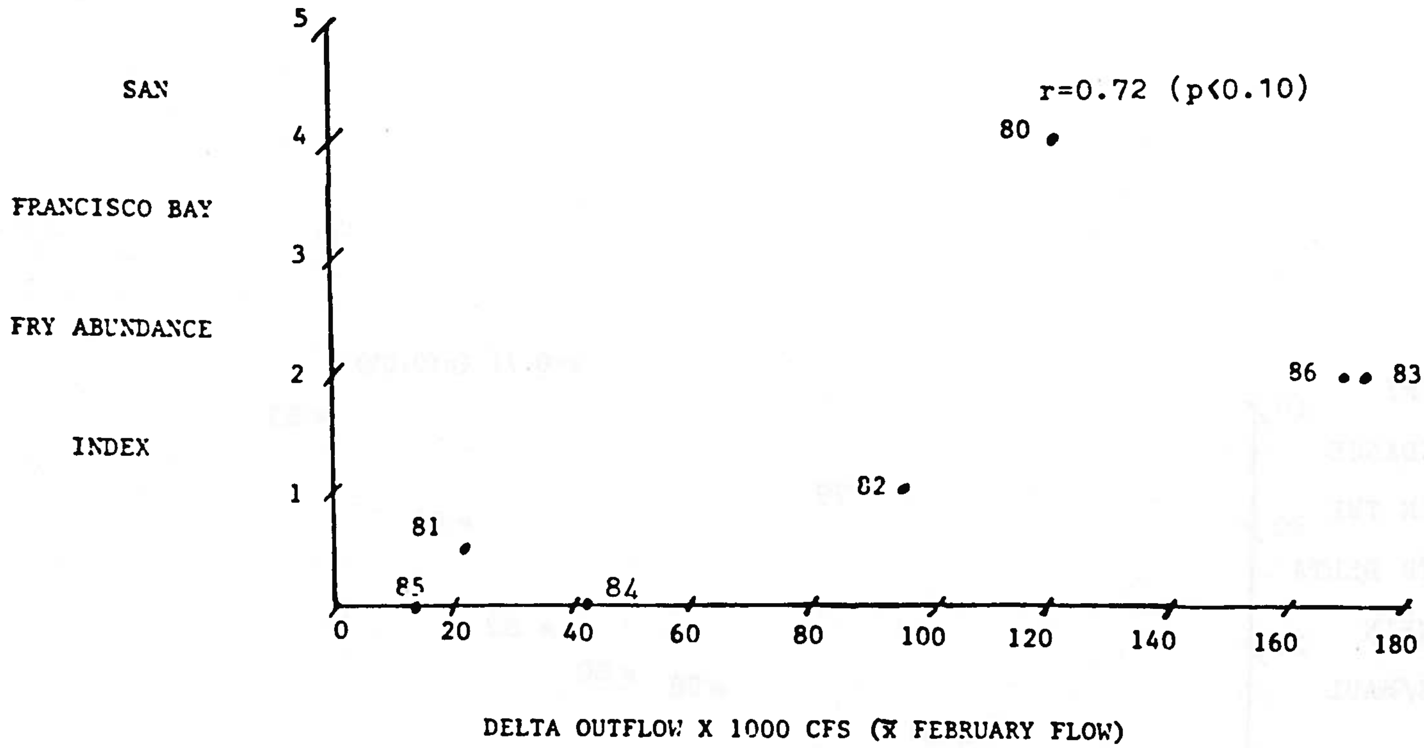

Figure 6-3. Relationship between our annual (February through April) San Francisco Bay fry index (catch per seine haul) and mean daily February Delta outflow in cfs.

Fry Survival

Our coded wire half tagged (CW1/2T) fry releases in the Bay, Delta and upper Sacramento River during late February or early March were designed to assess the differential survival of each release group. Survival was indexed by tag recovery rates from the ocean fishery (Appendix 30). This allowed us to make comparisons in river and estuarine survival between release groups for a given year but not between years since ocean conditions vary and thus could make comparisons invalid.

The ratio of CW1/2T fry recoveries indicate that survival of fry released in the north Delta (Courtland, Isleton, Ryde) was higher than for those released in the Central Delta (Mokelumne River) in dryer years (1981 and 1984) (Table 6-2). Fry released in the Central Delta were meant to represent fry that were diverted off the Sacramento River. This suggests that in dry years when more fry would be expected to be diverted off the Sacramento, their survival will be decreased. In the wet years of 1982 and 1983 the ratios of survival between the north and Central Delta of the two release groups were similar. This indicates that even those that are diverted into the Central Delta in wet years (probably a smaller fraction than in dry years) would not have greater mortalities than those that remained in the Sacramento.

The survival of CW1/2T fry released in San Francisco Bay (at Berkeley) from 1980 to 1982 was consistently lower than that for fry released in the Delta (Table 6-3) indicating that conditions in the Bay during those years were less favorable for rearing than

Table 6-2. Ratios of ocean tag recovery rates from CW1/2T (coded wire half tagged) salmon fry released in the North Delta (Courtland, Isleton and Ryde) and in the Central Delta (Mokelumne).

Year	North Delta	Central Delta	North Delta / Central Delta Ratio	Flow at I Street in February in cfs
1981	.0011	.0005	2.2	24,239
1982	.0005	.0004	1.3	59,646
1983	.0004	.0006	.7	79,039
1984	.0020	.0008	2.5	32,372

Table 6-3. Ocean tag recovery rates of CW1/2T salmon fry released at Red Bluff, in the North Delta and San Francisco Bay, the ratio between the Red Bluff and North Delta releases and mean February flow in cfs.

Year	Site Release	Ocean Tag Index Recovery Rate	Red Bluff Delta Ratio	Mean February Flow (I Street) in cfs
1980	Below Red Bluff Diversion Dam	.0071	3.2	52,576
	Clarksburg (Delta)	.0022		
	Berkeley (SFB)	.00004		
1981	Below Red Bluff Diversion Dam	.0016	1.5	24,239
	Isleton (Delta)	.0011		
	Berkeley (SFB)	.00008		
1982	Below Red Bluff Diversion Dam	.0037	7.4	59,646
	Isleton (Delta)	.0005		
	Berkeley (SFB)	.00009		
1983	Ryde/Courtland	.00042		79,039
1984	Below Red Bluff Diversion Dam	.0031	1.5	32,372
	Ryde/Courtland (Delta)	.0020		

in the Delta. While salinity was higher in the Bay in 1981 (25 ppt), which may have hindered survival, it should not have been a problem in 1980 and 1982 (16 and 15 ppt respectively). Wagner et al. (1969) found chinook fry could withstand salinities up to 20 ppt. We recovered CW1/2T fry by seine three to four weeks after release in the Bay in 1980 and 1982 indicating salinity did not cause immediate mortality for those release groups. Water turbidity is typically lower in the Bay which may cause higher predation losses than in Delta waters and this could explain the lower survival in the Bay.

Over the four year period of measurement, tag recovery rates for CW1/2T fry released in the upper Sacramento River below Red Bluff were consistently higher than those released in the Delta in the same years (Table 6-3, Appendix 30). The greatest difference between Delta and upriver fry survival as shown in Table 6-3 by using a ratio, appeared to be in 1980 and 1982 when Sacramento River inflow to the Delta was greatest (50,000 to 60,000 cfs in February at I Street). This may be due to increased rearing habitat in the upper Sacramento River with increasing flows since there is considerable portions of the upper Sacramento River that have a flood plain that becomes available for fry rearing at high flows. Such habitat is not present along the leveed Delta channels. Fry survival indices were more similar in both the Delta and upper Sacramento River in the drier years of 1981 and 1984.

Although we have the above comparisons between upper River and Delta fry survival, the relative importance of Delta fry rearing compared to that upstream has not been quantified. This is due to difficulties in accurately assessing relative fry densities in both Delta and upriver habitats. Given, however, that fry are present in the Delta and some do survive, we can conclude that they do contribute to adult salmon production. That contribution is probably higher in the wet years when we see the greatest numbers of fry in the Delta.

Summary

We have evidence that fall-run chinook fry rear in the Bay/Delta system. Estuarine fry catches increase and distribution broadens with greater inflow to the Delta. The survival of tagged fry in the north Delta appears to be higher than for those released in the Central Delta except in years of very high river flow. Fry survival is greater in the upper Sacramento River than in the Delta while that in central San Francisco Bay was the lowest for these three regions. Fry that rear in the Delta contribute some portion of Central Valley adult salmon production but we don't know how that compares to that of upstream rearing. The contribution is probably more significant in the Delta in high runoff years than in years of low runoff.

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<u>Summary</u>

We have evidence that fall-run chinook fry rear in the Bay-Delta system. Increasing fry catches increase and distribution broadens with greater inflow to the Delta. The survival of tagged fry in the north Delta appears to be higher than for those released in the Central Delta except in years of very high river flow. Fry survival is greater in the upper Sacramento River than in the Delta while that in central San Francisco Bay was the lowest for these three regions. Fry that rear in the Delta contribute some portion of Central Valley adult salmon production but we don't know how that compares to that of upstream rearing. The contribution is probably more significant in the Delta in high runoff years than in years of low runoff.

Section 7

ADULT ESTUARINE MIGRATIONS

Adult chinook migrating upstream are found in the Estuary throughout the year. Fall-run fish are present in the Estuary beginning in July and continuing into November. The late-fall run follows a month or two later in December and January. The greatest number of spawners are seen in the Estuary between October and February. The winter run migrates through the Delta from January to April, while the spring run is present from March through July (Figure 2-3).

No recent studies of adult chinook needs in the Bay/Delta Estuary have been undertaken. Essentially all of our knowledge on chinook upstream migration through the Estuary is the result of sonic tag studies done on returning fall-run fish from 1964 to 1967 (Hallock et al. 1970).

Both the Sacramento and San Joaquin stocks follow the salinity gradient through San Francisco Bay to the western Delta. Here fish from both river drainages must choose their path upstream. San Joaquin River salmon primarily utilize the mainstem San Joaquin although some use Old and Middle rivers (Hallock, et al. 1970).

The path of Sacramento basin chinook is more diverse. The majority probably follow the mainstream but some also use the lower forks of the Mokelumne River through the Central Delta. More salmon apparently are drawn to the Sacramento River water entering the Mokelumne and lower San Joaquin when cross Delta water transfers are high (Hallock et al 1970). The fish can reenter the main Sacramento River via Georgiana Slough and the Delta cross channel.

The presence of Sacramento River water in the Central and south Delta channels causes migration delays for salmon from both river basins (Hallock et al. 1970). The apparent value for "home stream" water for guidance to upstream spawning grounds indicates that positive downstream flow will enhance upstream migration. Reverse flows in the lower San Joaquin hamper or at least delay migration (Hallock et al. 1970).

Temperatures over 65^{O}F have partially blocked migrations in the San Joaquin River past Stockton and blocks of water with dissolved oxygen concentrations of less than 5 mg/l constitute a virtual barrier to adult migrants (Hallock et al. 1970). Low summer dissolved oxygen (DO) levels near Stockton in the 1960's and 1970's were attributed to low flows and high BOD loading from cannery wastes that were not adequately treated. Improved sewage treatment at Stockton in 1979 appear to have lessened the problem in recent years (DWR, Harlan Proctor, pers. comm.). Improved flows and water quality associated with New Melones operations may also have helped. Late summer and early fall dissolved oxygen levels since then have remained above 5 mg/l. Up to 1984 a partial rock barrier was constructed in upper Old River when DO levels were expected to be limiting to salmon migration. The barrier increased flows past Stockton and raised DO levels above 5 mg/l when flows past Stockton were over 400 cfs.

We found no relationship between the number of spawners returning to the San Joaquin and the amount of San Joaquin river flows present at Vernalis during September for the years 1958 to 1985. This suggests that flow levels during upstream migration are not a major factor in determining returning run size.

<u>Summary</u>

Salmon spawner migration through the Estuary appears to be helped with a positive downstream flow of "homestream water" and temperatures less than 66°F. Adult migrants need a path clear of obstructions and a dissolved oxygen concentration of more than 5 mg/l.

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Summary

Salmon spawner migration through the Estuary appears to be helped with a positive downstream flow of "homestream water" and temperatures less than 66°F. Adult migrants need a path clear of obstructions and a dissolved oxygen concentration of more than 5 mg/l.

Section 8

THE STATUS OF CENTRAL VALLEY CHINOOK STOCKS

The California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the U.S. Bureau of Reclamation have all, over the years, counted salmon at various times and places in the Central Valley. Fry (1961) described counts made as early as 1937. The early counts were irregularly made, usually for a specific purpose such as to establish mitigation levels for parts of the Central Valley and State Water Projects.

Since 1953, the Department of Fish and Game has made annual estimates of spawning fish on each of the major rivers. The counts include both grilse and adult fish from both natural and hatchery production. They are usually referred to as estimates of spawning "escapement" since they describe the numbers of chinook that have escaped the ocean fishery and returned to spawn.

The estimates are summarized in Appendix 10 and illustrated in the following figures. They are good evidence that the salmon spawning runs, since the regular counts started in 1953, have fluctuated greatly (Figure 8-1). The total runs plummeted from over 600,000 in 1953 to 120,000 in 1957, and then back up to almost 500,000 by 1960. In the last 20 years the total run has tended to be lower averaging about 250,000 to 300,000 fish.

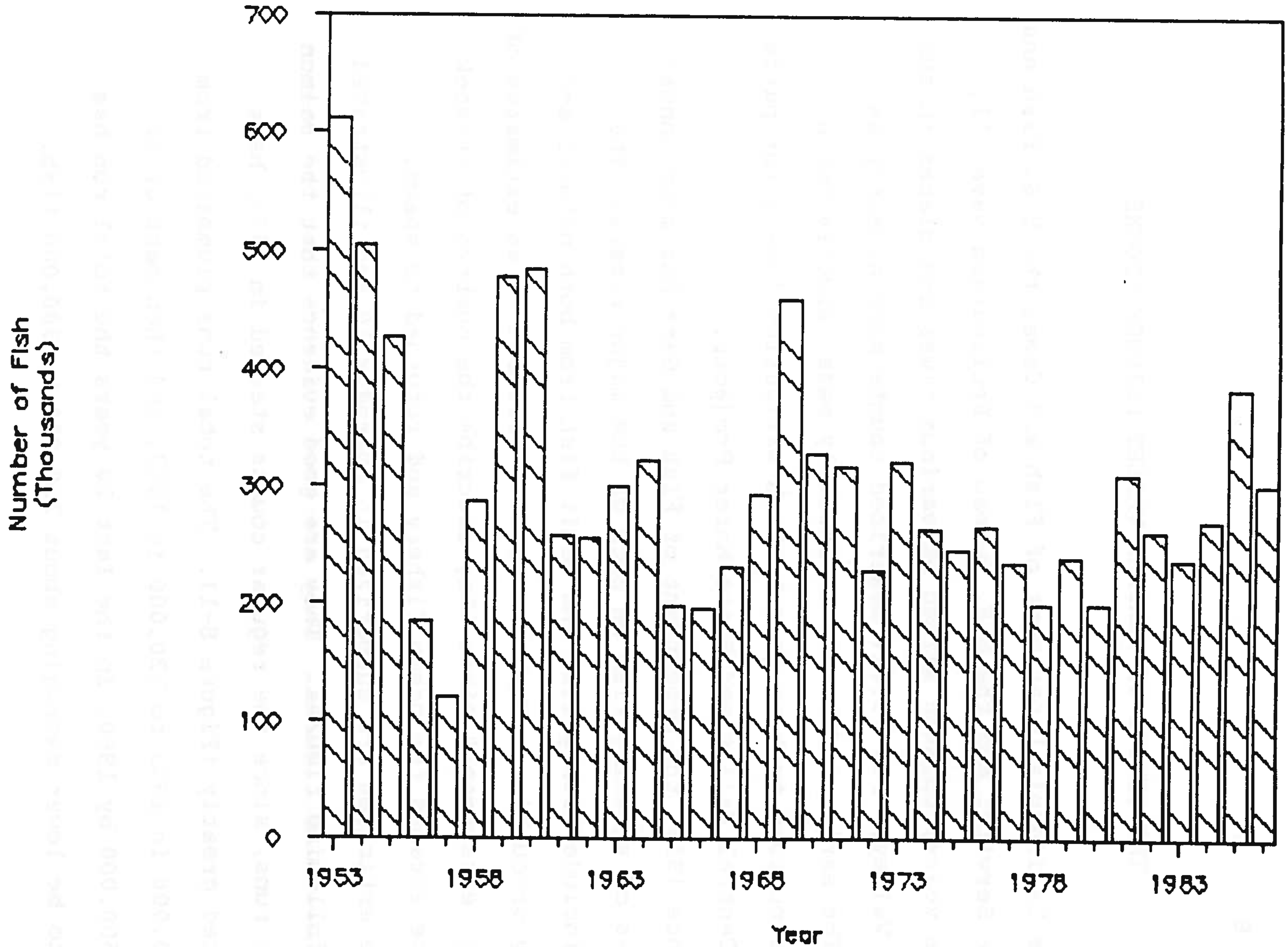

Figure 8-1. Total spawning escapement of Central Valley chinook salmon 1953-1987 (Taylor 1973, Reavis 1983, Pacific Fisheries Management Council 1984).

Upper Sacramento River Run

The upper Sacramento River has always supported the largest of the Central Valley chinook runs. Most are fall spawning fish whose young emigrate through the Delta either as fry that moved down with high flows during the winter or as larger smolts emigrating down in the spring. These runs declined from peak levels of 422,000 in 1953 to 77,000 in 1957, climbed in two years to 272,000, and then persistently dropped for the next 15 years (Figure 8-2). Since the 60s, this fall upper Sacramento River run has stabilized at levels of about 50% of those in the 1950s.

The winter run chinook was the next largest run. Counts of this run have only been possible since the Red Bluff Diversion Dam was built. Estimates based on these counts have declined until they are now only a few thousand fish. This upper Sacramento winter run and the late fall run are in serious trouble, and major efforts are being made to identify and correct the problems that are causing the declines (FWS Bay/Delta Hearing Exhibit 29).

The spring run on the upper Sacramento is the only one of the four not showing a recent declining trend. The numbers of spring run fish have fluctuated around 10,000 to 20,000 since 1969.

Sacramento River Tributaries

There are major chinook runs utilizing Battle Creek and the Feather, Yuba, and American rivers. There are also small runs on most of the other tributaries but they are not regularly counted. The Battle Creek runs appear to be recovering from the low levels of the late 1960s and 1970s (Figure 8-3). The Feather and the

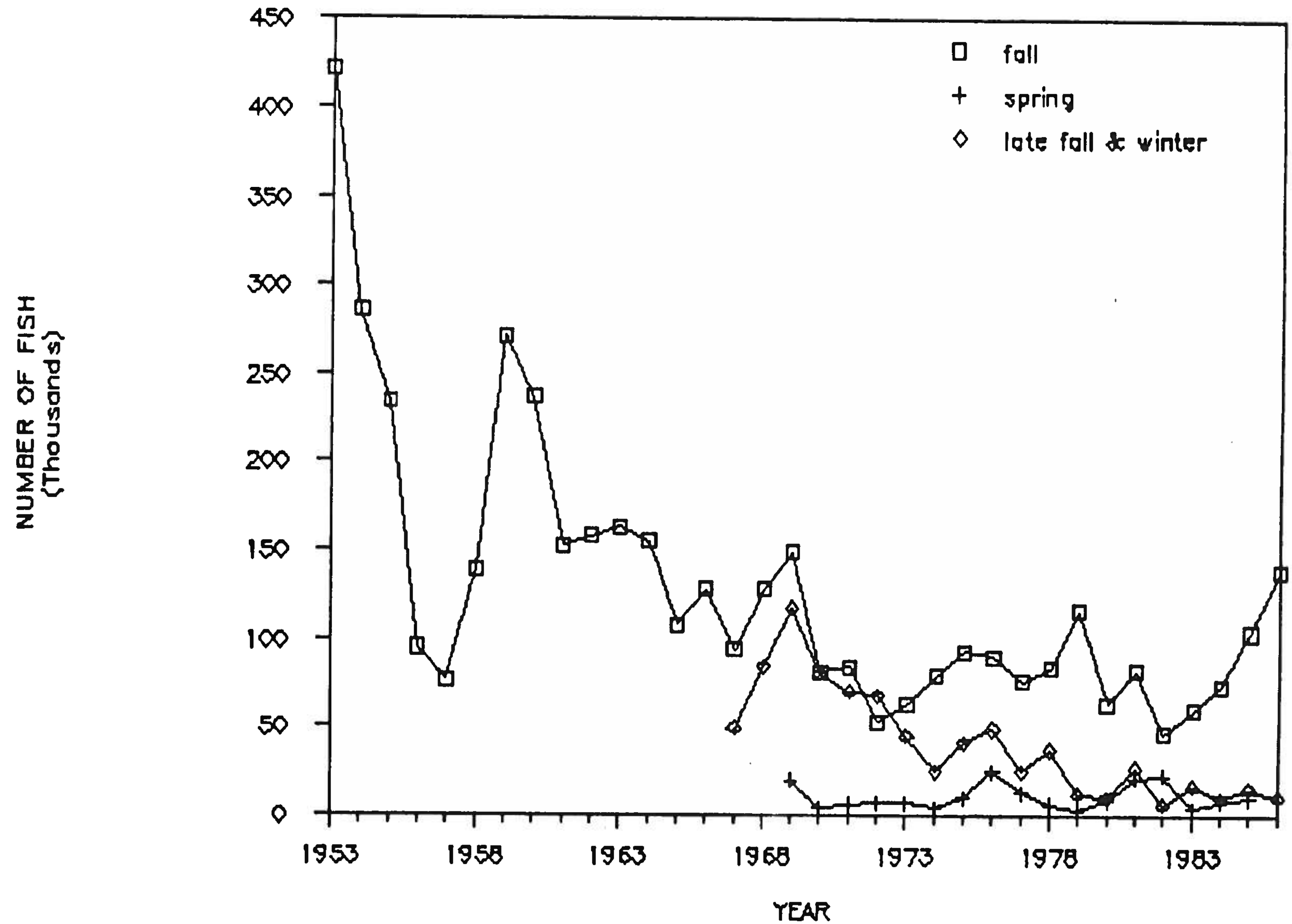

Figure 8-2. Annual estimates of fall run, spring run, and late fall and winter run of chinook salmon in the main Sacramento River (Taylor 1973, Reavis 1983, Pacific Fisheries Management Council 1984, Dettman, Kelley, and Mitchell 1987).

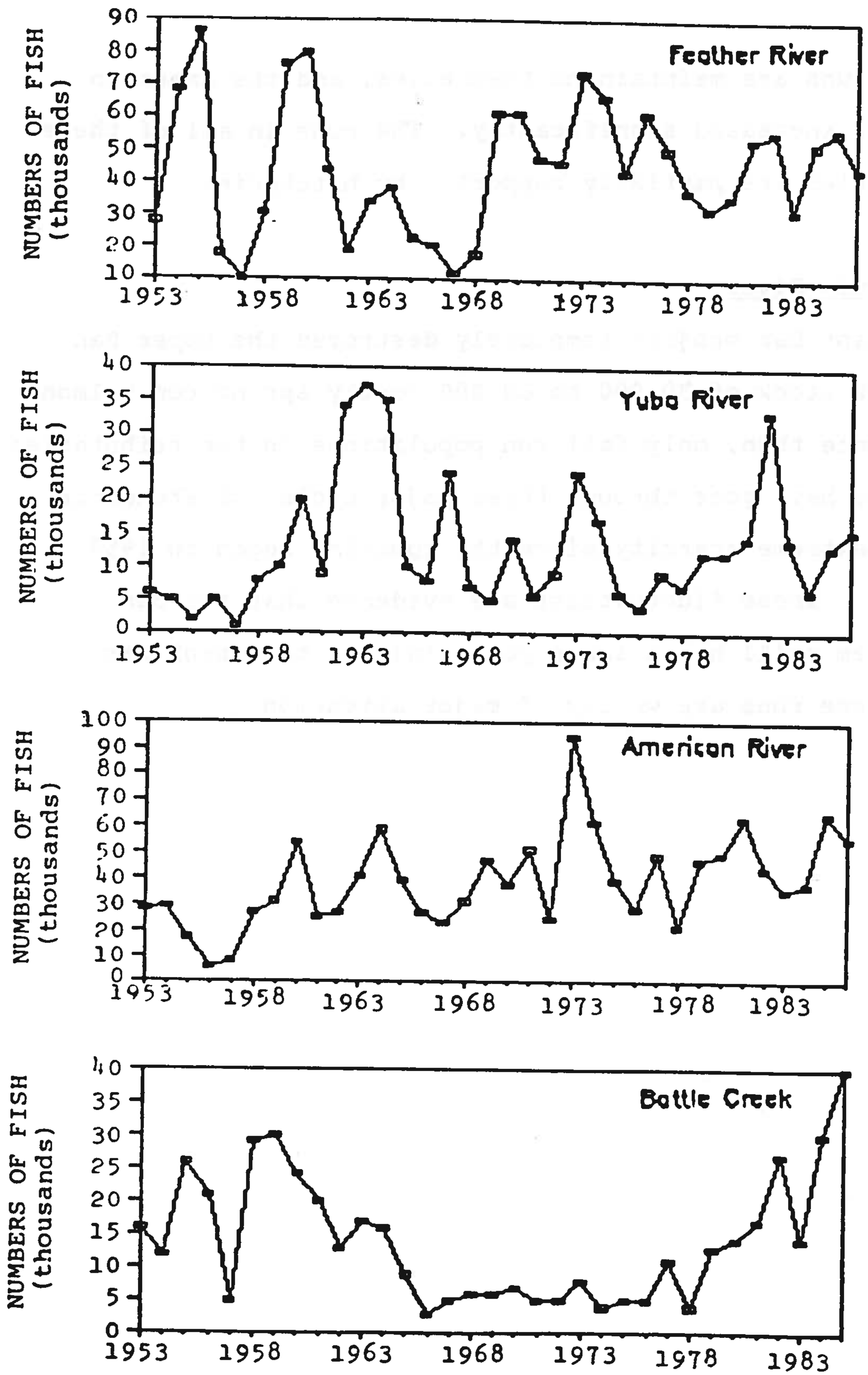

Figure 8-3. Annual estimates of fall chinook spawning in the principal tributaries of the Sacramento River. All but the Yuba River are partially supported by hatcheries (Taylor 1973, Reavis 1983, Pacific Fisheries Management Council 1984, and Dettman, Kelley, and Mitchell 1987).

Yuba rivers runs are maintaining themselves, and the American River run has increased significantly. The runs in all of these four tributaries are partially supported by hatcheries.

The San Joaquin River

The Friant Dam project completely destroyed the upper San Joaquin River stock of 30,000 to 60,000 mostly spring run salmon in 1949. Since then, only fall run populations in the tributaries remain. They have gone through three major cycles of abundance followed by extreme scarcity since the counting began in 1953 (Figure 8-4). These fluctuations are evidence that the San Joaquin system still has a large potential and that problems affecting these runs are worthy of major attention.

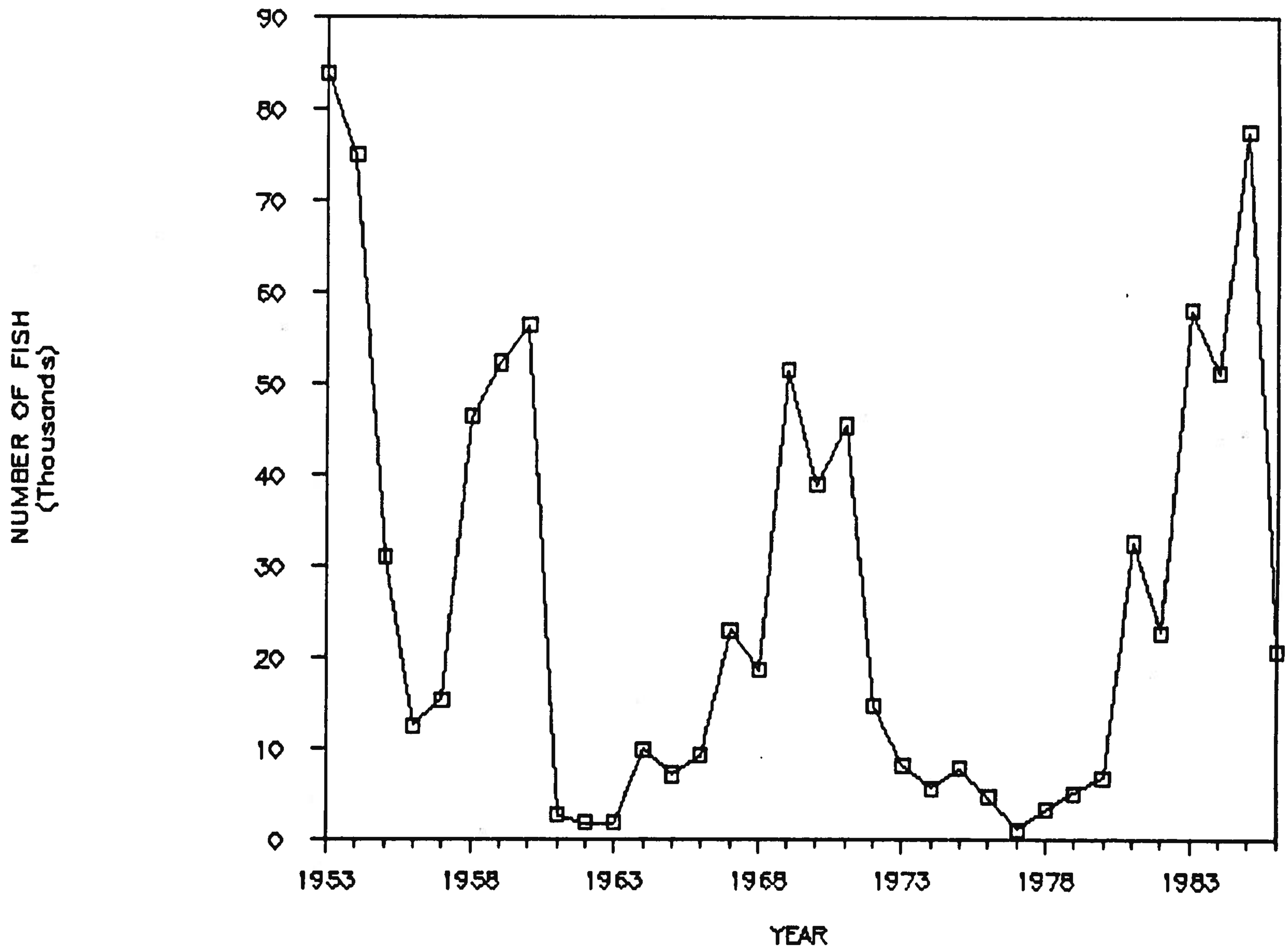

Figure 8-4. Annual estimates of fall run chinook spawning in the San Joaquin River tributaries (Taylor 1973. Reavis 1983, Pacific Fisheries Management Council 1984, and Dettman, Kelley, and Mitchell 1987).

Section 9

MANAGEMENT OF CENTRAL VALLEY CHINOOK

Chinook salmon production in California is affected not only by inland, estuarine and oceanic environments but also by man's harvest and hatchery management programs. This section is designed to give a brief overview of the influence of present management activities. Only through an appreciation of these actions combined with a definition of salmon habitat needs both inland and in the Bay/Delta system can a wise decision be made to achieve comprehensive protection for the chinook resource.

Major efforts also are expended by the State and Federal governments in the area of salmon habitat protection and enhancement. These activities are too numerous to summarize in this report but some will be the subject of the California Department of Fish and Game and U.S. Fish and Wildlife Service Hearing exhibits on upstream salmon needs.

Harvest Management

Central Valley salmon are primarily harvested by the ocean fishery off the California coast. The ocean sport and commercial fishery have taken an average of about 89,000 and 439,000 Central Valley chinook per year respectively, since 1975 (Figure 9-1, Appendices 31-33). About 35,000 salmon are believed to be taken by the inland sport fishery each year. Central Valley salmon provide about 65% of the total California chinook harvest in the

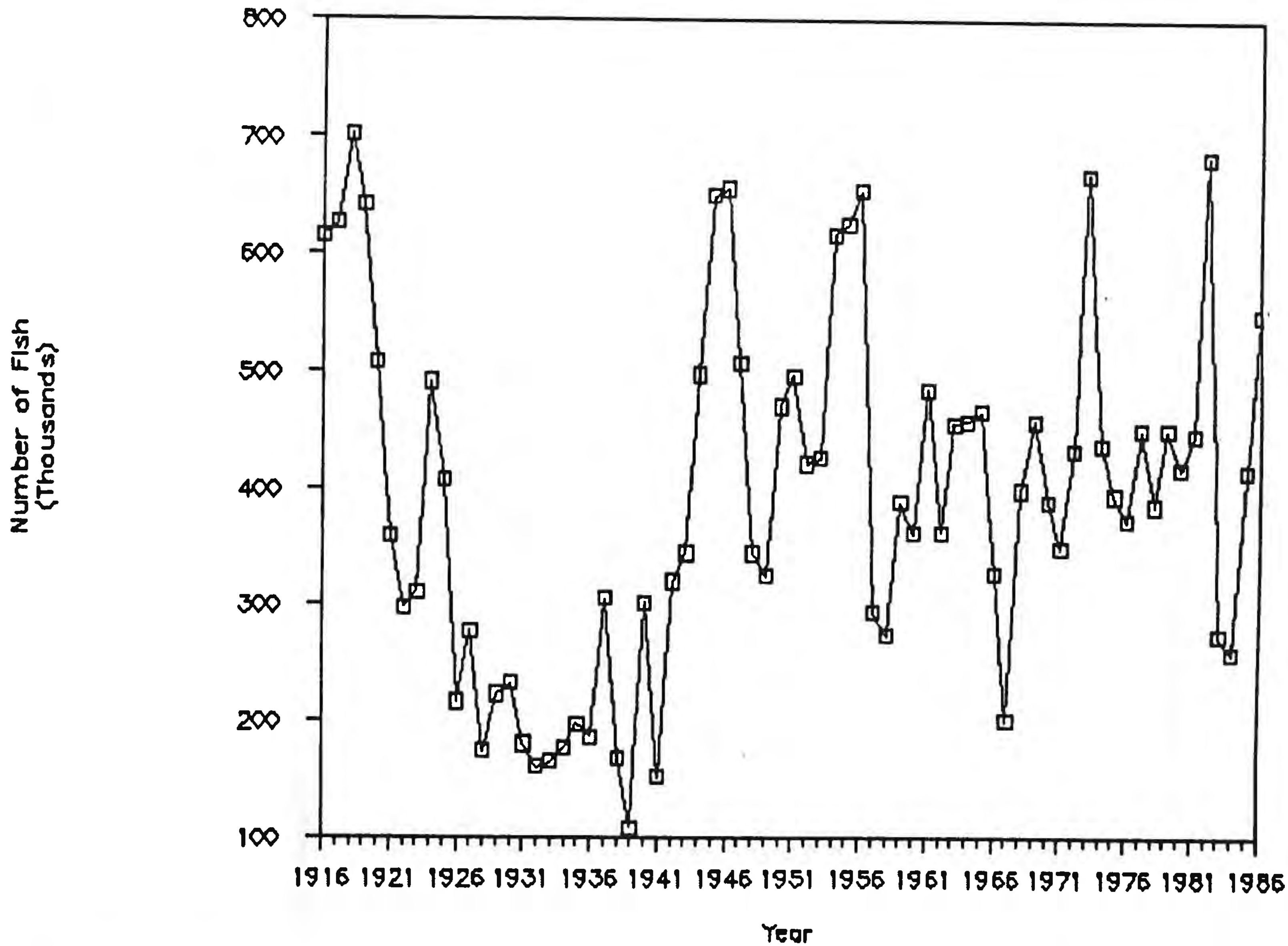

Figure 9-1. Estimates of total ocean sport and commercial catch and the estuarine gill net catch that was outlawed in 1957. No such estimates are available for the freshwater sport fisheries (Dettman, Kelley, and Mitchell 1987).

ocean. The California commercial troll fleet numbers about 2,500 vessels and expends about 50,000 days of effort per year (1984 to 1986), while the sport fishery averages 164,000 angler days annually (PFMC 1986).

The Pacific Fishery Management Council (PFMC) recommends regulations to the Secretary of Commerce affecting the harvest of salmon along the California, Oregon and Washington coasts. The PFMC relies upon the California Department of Fish and Game (CDFG) for data and input necessary to manage Central Valley chinook stocks. The CDFG and the California Fish and Game Commission are the management authorities for California fish and wildlife including territorial ocean waters off California (0 to 3 miles). The National Marine Fisheries Service (NMFS) has regulatory responsibility to implement annual harvest regulations proposed by the PFMC in federal waters (3 to 200 miles offshore).

The principal harvest management objectives affecting the PFMC's annual regulatory plans include: the establishment of ocean harvest rates to allow sufficient spawners for optimum natural production and to achieve production goals; a level of harvest that when both hatchery and natural stocks are fished, the weakest natural stocks for which specific objectives have been defined are sustained; and regulation of the fishery so that optimum catch provides for the social and economic values of the fishery (PFMC 1986).

Harvest management measures used to meet the above objectives in the ocean include: time and area closures, quotas, minimum size limits, recreational bag and possession limits and gear restrictions. The number of commercial vessels in the ocean fishery is presently limited by State authority.

The California Fish and Game Commission regulates the harvest of salmon inland through fishing seasons and areas, gear and methods of take and possession limits.

The PFMC ocean harvest rate index for the Central Valley chinook is defined by the ratio of the ocean chinook catch south of Point Arena divided by that catch plus the spawner escapement. The index has fluctuated from 52 to 74% between 1970 and 1985 and the trend has been relatively stable (PFMC 1986). The harvest rate index is believed to have increased in the last 30 years from a mean of about 50% in the 1950's to 65% in the 1980's (Reisenbichler 1986).

The key Central Valley chinook stock approved by the PFMC for ocean fishery management purposes is fall-run chinook of the Sacramento River basin. The PFMC escapement goal range for Sacramento fall run chinook is 122,000 to 180,000 adult spawners and has been met in all but two years since 1970, however, the returns have been increasingly dependent upon hatchery production (see discussion below). It is assumed by the PFMC that because of the overlapping ocean distribution of Central Valley chinook stock, attainment of the escapement goal range for Sacramento River fall chinook will protect the other Central Valley stocks from overfishing.

Hatchery Management

Natural populations of chinook salmon in the Central Valley have been supplemented by hatchery production through facilities operated by state or federal governments.

The U.S. Fish and Wildlife Service operates Coleman National Fish Hatchery on Battle Creek, southeast of Redding in the upper Sacramento Drainage. The California Department of Fish and Game operates salmon hatcheries on the Feather, American (Nimbus hatchery), and Mokelumne (Figure 2-2). The objective of these facilities is to compensate for habitat losses attributed to the damming of salmon streams for water and power resource development. The Merced River hatchery is a fishery enhancement facility operated by the CDFG.

The majority of Central Valley hatchery production is as fall-run smolts from Coleman, Nimbus, Mokelumne and Feather River hatcheries (Table 3-2; Appendices 4-8). Annual production goals from these facilities total about 20 million fall run smolts. Additional production of late-fall and spring run chinook takes place at the Coleman and Feather River facilities. Merced River hatchery primarily rears fall-run yearling chinook (Appendix 9). The relative contribution of hatchery salmon to the Central Valley spawning escapement probably varies widely and is difficult to estimate accurately. Spawner escapement attributed to hatchery chinook is relatively low for the upper Sacramento, (15-25%, Reisenbichler, 1986; U.S. Fish and Wildlife Exhibit 29) and San Joaquin system, (<5%, CDFG, William Laudermilk, pers. comm), while estimates are much higher (over 50%) for the Feather and American Rivers (Dettman et al. 1987).

Coleman hatchery releases its production in the upper Sacramento below Red Bluff Diversion Dam or in Battle Creek from April to June. Hence, all salmon from that hatchery migrate down the Sacramento and through the Delta and San Francisco Bay. Fish produced in the Merced River are released in the Merced River as yearlings in October and November and also migrate to sea via the Estuary.

Since the early 1970's juvenile chinook propagated at the Feather River, Nimbus and Mokelumne River hatcheries have been trucked downsteam and released at Rio Vista or near Carquinez Straits (since about 1981) at the upper end of San Pablo Bay. Since they are not exposed to upstream and Delta mortalities, their contribution to the ocean fishery and to subsequent spawning runs is often high. This is supported by ocean tag recovery rates of smolts released in Suisun Bay (at Port Chicago) when compared to those released at Sacramento (Discovery Park) (Figure 3-5). Nearly all of the Nimbus and Feather rivers hatchery production is trucked around the Delta and planted in the Bay.

However, the release location of juvenile salmon affects where the fish will return to spawn. Mental imprinting to guide later homing by spawners appears to take place during their downstream migration. Hence, salmon that migrate to the ocean the entire distance from where they were hatched are more likely to return to their natal streams than those that are trucked downstream for release. Available coded wire tagged recoveries of tagged hatchery fish that were released in various locations in the Central Valley indicates that fish trucked to the Estuary are more likely to stray than those released in their stream of birth (Hallock and Reisenbichler 1979, Dettman et al 1987). Because of this, hatchery production is released in the upper Sacramento and Merced rivers and not trucked downstream.

There is concern that this straying may harm the "genetic integrity" of wild stocks. We believe that the fall, spring, late fall, and winter runs of salmon utilizing the Central Valley are genetically distinct. We do not yet know whether this is true of the fall run California chinook in the different rivers.

The program of rearing chinook to smolt size and trucking them around the environmental dangers of the Sacramento River and the Delta has proven successful in terms of maintaining the ocean fishery. Because of the high straying rates of these trucked fish, they may also be maintaining the run in the Yuba and helping reduce the decline in the upper Sacramento. The very success of the hatchery program, however, increases the risk of overharvesting natural stocks or Coleman Hatchery fish that must pass down the Sacramento River and through the Delta. Actions to increase the survival rates of those emigrants are a critical element in making the hatchery program compatible with the natural reproduction.

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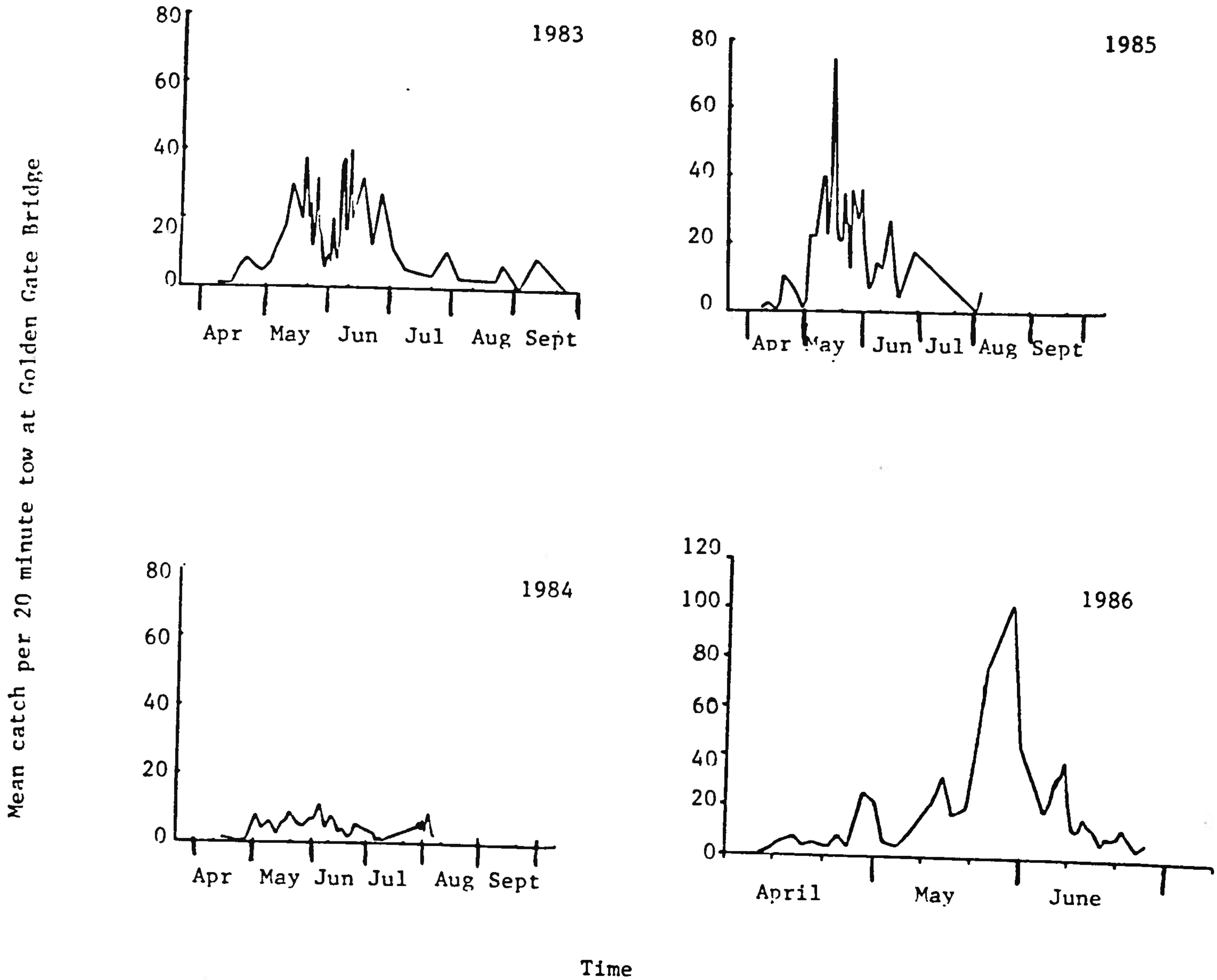
Appendix 1

Relative Abundance Indices Based on Midwater Trawl Samples

Methodology

Annual relative abundance indices of fall-run smolts that were leaving the Delta were estimated from 1978 to 1986 by sampling 2 to 7 days/week during daylight hours at Chipps Island near Pittsburg, California with a 9.1 by 7.9 m (3.2 mm mesh, code end) midwater trawl. The trawl fished approximately the upper one half of the water column where over 90% of the smolts are found during daylight (Wickwire and Stevens, 1970). Ten tows/sampling day were taken from April through June. Abundance indices equaled the mean catch per 20 minute tow. Tows were generally made against the current and distributed across the channel with 3 or 4 tows per day made on the north, middle and southern portion of the channel. Engine speed was held constant during each tow to keep the volume sampled/tow consistent.

Another relative smolt abundance index was gained using an identical size midwater trawl at the Golden Gate Bridge in San Francisco Bay. That sampling occurred primarily from April through July from 1983 to 1986.



Appendix 2. Mean midwater trawl catch per 20 minute tow at the Golden Gate Bridge versus time.

Appendix 3. Distribution (percent) of total midwater trawl catch of smolts by month for San Francisco Bay at the Golden Gate Bridge.

Year	April	May	June
1983	10	39	51
1984	8	50	42
1985	9	63	28
1986	12.5	62.5	25
$\bar{x}$	10	54	36

Appendix 4. Coleman National Fish Hatchery fall run chinook production releases by release year (BY+1) from 1978 to 1986[1]. All production released in the Upper Sacramento River unless noted otherwise.

Release Year	Fry(<1gm)	Fingerling(1-5gm)[2]	Smolts(5-10gm)	Yearings(<10gm)	Total
78	0	5,306,800 1,425,908 (released at Rio Vista)	0	941,450	7,674,158
79	0	4,508,792	43,075	2,557,041	7,108,908
80	294,802	12,153,985	0	614,909	13,063,696
81	155,687	327,017	14,062,281	0	14,544,985
82	402,121	8,590,094	0	0	8,992,215
83	5,346,910	11,789,790	0	441,178	17,578,078
84	3,163,932	9,764,601	0	302,107	13,230,640
85	11,851,640	6,534,597	6,464,920	0	24,851,157
86	0	15,023,392	0	0	15,023,392

1/ Numbers derived from CNFH annual and monthly hatchery distribution reports.

2/ Most fingerlings are believed to be close to 5 gm (90/lb).

Appendix 5. Coleman National Fish Hatchery fall run chinook production releases by release year (BY+1) from 1968-1977.[1/] All production released in the Upper Sacramento River unless noted otherwise.

Release Year	Fingerling & Smolts (1-10gm)	Yearlings(<10gm)	Total
68*	2,994,000	7,363,000	10,357,000
69*	1,278,000	2,231,000	3,509,000
70*	2,947,000	3,057,000	6,004,000
71*	5,129,000	2,519,000	7,648,000
72*	7,203,000	--	7,203,000
73*	4,697,000	--	4,697,000
74	4,927,800	--	4,927,800
75	1,910,212	--	1,910,212
76	2,801,000	1,112,000	3,913,000
77	5,519,000	593,000	6,112,000

* Combined fall and late fall production.

1/ Reference: Report of the USFWS on Problem A-6 of the Central Valley Fish and Wildlife Managment Study 5-82.

Appendix 6 Number of juvenile fall chinook salmon reared at Nimbus Salmon and Steelhead Hatchery and released into the Sacramento Basin: upstream of the cross channel, at Rio Vista, and downstream of Rio Vista for brood years 1968-84, through July 1, 1985. Source: Log of daily plants from Nimbus Hatchery. Complied by D. W. Kelley and Associates.

LOCATION		Number of Fish Planted by Brood Year																
		1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
UPSTREAM OF CROSS CHANNEL																		
Weight Range	grams																	
Fry	(1 g	1,059,910	586,780	7,921,690	783,140	360,505	0	232,555	1,844,810	530,513	191,520	857,344	2,621,713	13,563,100	8,065,484	2,900,045	1,341,335	9,290,380
Fingerling	1 - 5 g	231,103	1,351,533	13,626,692	1,260,495	1,885,185	0	235,380	339,225	87,881	138,600	0	137,445	0	0	52,800	381,250	710,400
Smolt	5 - 10 g	1,430,541	1,435,928	1,042,082	147,610	0	0	72,250	551,600	1,826,445	0	18,375	0	0	0	0	0	0
Yearling	) 10 g	0	32,985	171,175	253,635	221,710	184,075	214,935	127,170	31	0	0	0	0	0	0	0	0
	Subtotal	2,721,554	3,407,226	22,761,639	2,444,880	2,467,400	184,075	755,120	2,862,805	2,444,870	330,120	875,719	2,759,158	0	8,065,484	2,952,845	1,722,585	10,000,780
AT RIO VISTA																		
Weight Range	grams																	
Fry	(1 g	0	0	0	0	0	25,705	0	0	0	0	180,000	0		0	0	0	0
Fingerling	1 - 5 g	198,360	278,328	92,182	1,013,600	1,604,680	0	1,733,655	1,391,375	999,450	1,159,400	1,896,065	0		320,025	0	0	0
Smolt	5 - 10 g	554,815	511,640	268,529	95,700	640,400	220,000	136,200	1,253,450	1,796,800	3,528,445	4,032,290	3,346,783		1,835,900	153,000	0	0
Yearling	) 10 g	108,240	10,830	0	0	0	0	0	0	0	229,040	267,460	198,012		0	0	0	0
	Subtotal	861,415	800,798	360,711	1,109,300	2,245,080	245,705	1,869,855	2,644,825	2,796,250	4,916,885	6,375,815	3,544,795	0	2,155,925	153,000	0	0
DOWNSTREAM OF RIOVISTA																		
Weight Range	grams																	
Fry	(1 g			0	0								0	1,107,320	0	0	0	0
Fingerling	1 - 5 g			201,559	1,202,900								0	906,927	0	2,018,900	0	0
Smolt	5 - 10 g			256,553	0								0	3,476,270	521,200	2,124,700	2,614,650	4,383,000
Yearling	) 10 g			0	0								270,281	335,570	2,116,330	391,090	668,910	177,700
	Subtotal	0	0	458,112	1,202,900	0	0	0	0	0	0	0	270,281	5,826,087	2,637,530	4,534,690	3,283,560	4,560,700
TOTALS BY BROOD YEAR		3,582,969	4,208,024	23,580,462	4,757,080	4,712,480	429,780	2,624,975	5,507,630	5,241,120	5,247,005	7,251,534	6,574,234	5,826,087	12,858,939	7,640,535	5,006,145	14,561,480

ppendix 7. Mokelumne River Fish Installation (MRFI) fall run chinook hatchery production releases by release year (BY+1) from 1965-1986.[1/]

Release Year	Number Fingerlings & Smolts	Site Released	Number Yearlings	Site Released
65	74,000	MRFI	0	--
66	76,000	MRFI	0	--
67	77,000	MRFI	0	--
68	178,000	MRFI	0	--
69	38,000	MRFI	0	--
70	497,000	MRFI	0	--
71	565,000	MRFI	0	--
72	561,000	MRFI	0	--
73	41,000	MRFI	0	--
74	176,000	MRFI	55,000	MRFI
75	7,000	MRFI	50,000	MRFI
76	68,000	MRFI	52,000	MRFI
77	71,000	MRFI	163,000	MRFI
78	0		743,000	Rio Vista
79	0		827,000	Rio Vista
80	105,000	MRFI	950,000	Rio Vista
81	105,050	MRFI	1,075,000	Rio Vista
82	170,000	MRFI	1,041,000	Rio Vista
83	89,000	MRFI	768,000	San Pablo Bay
84	0		811,000	San Pablo Bay
85	0		1,367,000	San Pablo Bay
86	0		1,972,000	San Pablo Bay

1/ Data was obtained from State of California office memo to Richard Beland from Region 2, subject: The Mokelumne River: Make-do salmon management, dated August 16, 1982. Updated by Fred Meyer per. comm. (CDFG) 6/10/87

Appendix 8 Number of juvenile fall chinook salmon reared at Feather River Salmon and Steelhead Hatchery and released into the Sacramento Basin: upstream of the cross channel, at Rio Vista, downstream of Rio Vista, at Mokelumne River Fish Installation, and into miscellaneous locations for brood years 1968 to 1985, through Sept 3, 1986. Source: Log of daily plants from Feather River Hatchery. Compiled by D. W. Kelley and Associates.

Number of Fish Planted by Brood Year

LOCATION		1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
UPSTREAM OF CROSS CHANNEL																			
Weight Range	grams																		
Fry	(1 g	9,600	345,000	127,642	859,000	3,267,280	1,136,000	1,811,760	0	0	318,976	0	0	6,267,200	3,499,060	2,844,785	862,200	182,400	259200
Fingerling	1 - 5 g	0	0	4,466,686	0	1,794,010	0	2,733,288	0	175,000	100,480	0	50,000	0	2,144,700	102,534	0	122,800	22800
Smolt	5 - 10 g	1,101,600	2,175,400	4,116,930	74,250	837,090	2,034,900	0	204,700	74,100	371,952	112,500	496,992	350,900	0	102,660	66,600	200,400	104000
Yearling	) 10 g	0	774,200	865,550	1,048,477	793,264	696,110	843,045	788,860	687,621	1,556,759	0	1,715,448	1,560,225	1,487,944	1,267,916	. 0	28,900	0
	Subtotal	1,111,200	3,294,600	9,576,808	1,981,727	6,691,644	3,867,010	5,388,093	993,560	936,721	2,348,167	112,500	2,262,440	8,178,325	7,131,704	4,317,895	928,800	534,500	386,000
AT RIO VISTA																			
Weight Range	grams																		
Fry	(1 g	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fingerling	1 - 5 g	0	0		1,579,300	122,185	743,700	1,182,225	107,500	0	687,000	412,200	0	0	0	0	0	0	0
Smolt	5 - 10 g	1,052,000	72,000		254,200	923,825	2,471,850	3,300,739	2,610,880	1,296,170	877,780	1,768,350	526,150	9,450	0	0	0	0	0
Yearling	) 10 g	0	0		160,750	0	0	84,000	0	25,650	0	0	170,300	0	27,675	36,000	0	0	0
	Subtotal	1,052,000	72,000	0	1,994,250	1,046,010	3,215,550	4,566,964	2,718,380	1,321,820	1,564,780	2,180,550	696,450	9,450	27,675	36,000	0	0	0
DOWNSTREAM OF RIOVISTA																			
Weight Range	grams																		
Fry	(1 g					0	0	0	0		0	0	0	0	0	0	0	0	0
Fingerling	1 - 5 g					100,000	0	0	0		0	0	0	104,500	1,040,670	0	0	0	0
Smolt	5 - 10 g					0	153,376	124,942	233,500		300,420	213,019	174,975	2,432,856	1,720,200	1,488,350	86,850	1,907,584	1174450
Yearling	) 10 g					0	0	0	20,250		149,000	170,765	243,200	1,148,635	665,379	182,100	2,465,450	6,512,055	2999401
	Subtotal	0	0	0	0	100,000	153,376	124,942	253,750	0	449,420	383,784	418,175	3,685,991	3,426,249	1,670,450	2,552,300	8,419,639	4,173,851
TRANSFERED TO MOKELUMNE RIVER HATCHERY																			
Weight Range	grams																		
Fry	(1 g										0	0	0		0	0	0	0	0
Fingerling	1 - 5 g										0	278,800	900,350		333,000	1,604,870	1,308,195	3,074,200	3,227,975
Smolt	5 - 10 g										693,750	231,000	606,840		0	0	210,760	0	0
Yearling	) 10 g										0	0	0		0	0	0	0	0
	Subtotal	0	0	0	0	0	0	0	0	0	693,750	509,800	1,507,130	0	333,000	1,604,870	1,518,955	3,074,200	3,227,975
MISCELLANEOUS RELEASES																			
Weight Range	grams																		
Fry	(1 g					0	0	0	0	0	0					49,500	0	0	0
Fingerling	1 - 5 g					200,800	0	0	0	0	0					202,934	67,600	0	0
Smolt	5 - 10 g					0	153,625	94,665	104,820	662,050	0					290,300	208,530	302,160	417,700
Yearling	) 10 g					0	0	0	0	0	22,500					0	0	14,040	0
	Subtotal	0	0	0	0	200,800	153.625	94,665	104,820	662,050	22,500	0	0	0	0	493,234	276,130	316,200	417,700
TOTALS BY BROOD YEAR		2,163,200	3,366,600	9,576,808	3,975,977	8,038,454	7,389,561	10,174,664	4,070,510	2,920,591	5,078,617	3,186,634	4,884,255	11,873,766	10,318,628	8,122,449	5,276,185	12,344,539	8,205,526

ɔpendix 9. Merced River Fish Facility fall run chinook hatchery production releases by release year (BY+1) from 1971 to 1985.1/

Release Year	Number Fingerlings & Smolts	Site Released	Number Yearlings	Site Released
71	59,100	Merced River	0	--
72	1,500	Merced River	202,000	Merced River
73	0	--	286,000	Merced River
74	0	--	176,500	Merced River
75	0	--	0	--
76	0	--	80,000	Merced River
77	75,000	Merced River	0	--
78	100,000	Merced River	245,000	Merced River
79	0	--	16,940	Merced River
80	0	--	0	--
81	0	--	276,850	Merced River
82	102,572	Merced River	251,915	Merced River
83	0	--	145,657	Merced River
84	0	--	275,380	Merced River
85	789,556	Merced River	371,350	Merced River

1/ Reference: California Department of Fish and Game, Annual reports from Merced River Hatchery.

Appendix 10. Annual estimates of total (grilse plus adults) chinook spawning escapement in the Sacramento and San Joaquin Basins, 1953 to 1984 (Dettman et al. 1987).

	SACRAMENTO BASIN FALL RUN CHINOOK							TOTAL	SACRAMENTO BASIN				TOTAL of
YEAR	Sacramento River Mainstem[1]	Feather River	Yuba River	American River	Battle Creek	TOTAL	San Joaquin Basin Fall-Run	Central Valley Fall-run	Spring	Latefall & winter	TOTAL	Misc Others	Central Valley Runs
1953	422000	28000	6000	28000	16000	500000	84000	584000	15000	nc	15000	13000	612000
1954	286000	68000	5000	29000	12000	400000	75000	475000	18000	nc	18000	12000	505000
1955	234000	86000	2000	17000	26000	365000	31000	396000	26400	nc	26400	4000	426400
1956	95000	18000	5000	6000	21000	145000	12500	157500	19000	nc	19000	9000	185500
1957	77000	10000	1000	8000	5000	101000	15400	116400	3600	nc	3600	200	120200
1958	139000	31000	8000	27000	29000	234000	46500	280500	7000	nc	7000	200	287700
1959	272000	76000	10000	31000	30000	419000	52400	471400	6300	nc	6300	1000	478700
1960	237000	80000	20000	54000	24000	415000	56400	471400	13000	nc	13000	50	484450
1961	153000	44000	9000	25000	20000	251000	2700	253700	4000	nc	4000	1000	258700
1962	158000	19000	34000	27000	13000	251000	1800	252800	4200	nc	4200	0	257000
1963	163000	34000	37000	41000	17000	292000	1800	293800	7100	nc	7100	500	301400
1964	155000	38000	35000	59000	16000	303000	10000	313000	8300	nc	8300	1000	322300
1965	108000	23000	10000	39000	9000	189000	7200	196200	1800	nc	1800	200	198200
1966	128000	21000	8000	27000	3000	187000	9300	196300	500	nc	500	300	197100
1967	94000	12000	24000	23000	5000	158000	23100	181100	500	49533	500	0	231133
1968	128000	18000	7000	31000	6000	190000	18700	208700	700	84414	700	100	293914
1969	149000	61000	5000	47000	6000	268000	51600	319600	21300	117808	21300	1100	459808
1970	81500	61300	14000	37600	7000	201400	39000	240400	8000	81159	8000	0	329559
1971	84000	47500	5700	51200	5000	193400	45500	238900	9500	70000	79500	0	318400
1972	52800	46600	9000	24100	5000	137500	14700	152200	8400	68000	76400	0	228700
1973	62800	73500	24000	94500	8000	262800	8200	271000	7200	45000	52200	0	323200
1974	79600	66400	17000	62000	4000	229000	5600	234600	4200	25000	29200	0	263800
1975	93400	43300	6000	39400	5000	187100	7800	194900	10700	41000	51700	0	246600
1976	90300	61200	3800	28200	5000	188500	4700	193200	25700	49000	74700	0	267900
1977	76200	50400	9000	48900	11000	195500	1100	196600	13200	25000	38200	0	234800
1978	83900	37800	7000	21200	4000	153900	3200	157100	6200	37100	43300	0	200400
1979	116600	32200	12000	47200	13000	221000	5100	226100	3300	12000	15300	0	241400
1980	63500	35700	12000	49500	14000	174700	6800	181500	9700	10000	19700	0	201200
1981	82200	53300	14000	63600	17000	230100	32600	262700	22000	27000	49000	0	311700
1982	46500	55600	33000	43900	27000	206000	22800	228800	27400	6100	33500	0	262300
1983	59900	31300	13800	35300	14000	154300	58200	212500	8000	17000	25000	0	237500
1984	73800	51600	6400	37800	30000	199600	51300	250900	10900	9700	20600	0	271500

Appendix 10. Annual estimates of total (grilse plus adults) chinook spawning escapement in the Sacramento and San Joaquin Basins, 1953 to 1984 (Dettman et al., 1987).

	SACRAMENTO BASIN FALL RUN CHINOOK							TOTAL	SACRAMENTO BASIN				TOTAL of
YEAR	Sacramento River Mainstem	Feather River	Yuba River	American River	Battle Creek	TOTAL	San Joaquin Basin Fall-Run	Central Valley Fall-run	Spring	Latefall & winter	TOTAL	Misc Others	Central Valley Runs
1985[3]	104000	56000	13000	65000	40000	278000	77600	355600	15200	15200	30400	0	386000
1986[3]	138600	44700	15300	55400	___[2]	254000	20800	274800	18100	10700	28800	0	303600

nc = no count

Sources: 1953-1969 (Taylor 1973)
1964-1981 (Reavis 1983)
1968-1970 Late fall and winter run (Halloch and Fisher 1985)
1970-1984 (PFMC 1985)
1985-1986 (Reavis, unpublished)

[1] Includes minor runs into tributaries, except Battle Creek.
[2] Included in Sacramento River mainstem estimates.
[3] Preliminary subject to revision.

Appendix 11. Mean midwater trawl catch per 20 minute tow at the Golden Gate Bridge during April, May and June from 1983 to 1986.

Year	April	May	June	Annual Mean
1983	4	16	21	17
1984	1	6	5	5
1985	4	29	13	20
1986	6	30	12	15

Appendix 12

Total Smolt Abundance Estimates
Based on Expanded Midwater Trawl Samples

Methodology

The annual number of fall-run smolts passing Chipps Island, N, was estimated from the equation $N_i = \frac{n_i}{t_i(.0055)}$, where n_i = total number of smolts collected by the midwater trawl during the April through June outmigration period of year i, t_i = the fraction of time the trawl sampled during the entire migration period and 0.0055 equals the estimated average fraction of smolts passing Chipps Island that are collected by the midwater trawl.

We estimated the fraction collected by the trawl (0.0055) by dividing the trawl catch of CWT smolts by the estimated "known" number of CWT smolts that were passing Chipps Island divided by the fraction of time sampled. The "known" numbers of CWT smolts were estimated by multiplying our estimated Delta survival rate of a given year times the number of CWT smolts released in the north Delta that same year. For example, in 1980 we estimated Delta survival of CWT smolts to be 41%. A total of 183,000 CWT smolts were released in the north Delta that year indicating about 75,000 should have survived to pass our trawl site. Dividing the total number of CWT smolts caught in 1980 (65) by the estimate of 75,000 smolts and then dividing that quotient by the fraction of time sampled (.136) yields the fraction 0.0063. The average fraction for the years 1980 to 1984 was 0.0055.

The fraction 0.0055 is very similar to the fraction derived if one assumes the catch efficiency of the net in turbid Delta waters is 100%, that the salmon vertical distribution makes them fully available to the trawl when they are in its path, and the width of the trawl when fishing is about 6.5 meters or about 70% of the total width (9.1 m). Field observations and the work of Watson et al., (1984) indicates that the 70% value is reasonable. The width of the channel is about 1200 m. Therefore, the net would fish, $\frac{6.5\ m}{1200\ m}$, or 0.0054 of the channel width. This approximation suggests that on the average the midwater trawl is very efficient.

Appendix 13. Coded wire tagged smolt release and recovery information for Delta survival (S_o) estimates using expanded ocean tag recoveries[1/].

Year Released, Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	4 or older	Total Recoveries (Expanded)	Recovery Rate	Estimated Delta Survival	Adjusted Delta Survival[2/]
1969									
Sacramento Fin Clip	250299	6/12-27	32*	384	95	511	.0020		
Rio Vista Fin Clip	252904	6/12-27	55*	675	115	845	.0033	.611	.50
1970									
Sacramento Fin Clip	258495	5/18 and 6/24	292*	841	112	1245	.0048		
Rio Vista Fin Clip	263064	5/18 and 6/24	782*	3816	477	5075	.0193	.249	.14
1971									
Sacramento Fin Clip	256845	5/26 and 6/8	119*	2374	448	2941	.0115		
Rio Vista Fin Clip	257213	5/26 and 6/8	208*	2100	479	2787	.0108	1.0	.99
1978									
6-62-2 Sacramento	162253	6/6	24	35	0		.0004		
6-62-3 Port Chicago	164766	6/5	881	4549	87	5517	.0330	.02	
1979									
6-62-5 Sacramento	160151	6/5	1	80	20	101	.0006		
6-62-6 Port Chicago	110122	6/6	53	713	89	855	.0077	.08	

* Sport catch only.

Appendix 13 (continued)

1980								
6-62-8 Sacramento	98586	6/2&3	112	922	24	1058	.0107	
6-62-11 Sacramento	84642	6/4&5	54	701	21	775	.0092	.0099
6-62-9 Port Chicago	88700	6/10	266	1746	47	2059	.0232	
6-62-12 Port Chicago	79443	6/13	291	1687	32	2010	.0253	.024
								.41
1981								
6-62-14 Sacramento	71932	6/2	21	4	0	25	.00034	
6-62-17 Sacramento	68318	6/5	4	15	3	22	.00032	.00034
6-62-15 Port Chicago	78339	6/8	318	1827	42	2186	.0279	
								.01
1982								
6-62-18 Sacramento (CNFH)3/	89780	5/12	25	770	279	1076	.0120	
6-62-20 Sacramento (FRH-May)	85885	5/11	26	1065	182	1284	.0150	
6-62-19 Port Chicago (CNFH)	86877	5/17	21	467	285	777	.0090	
6-62-21 Sacramento (FRH-June)	60822	6/5	7	277	112	396	.0065	
6-62-22 Port Chicago June	63221	6/8	5	273	90	368	.0058	
								1.12

Appendix 13 (continued)

1983								
6-62-24 Courtland	96706	5-16	20	288	39	347	.0036	
6-62-30 Port Chicago	43374	5/23	18	88	21	126	.0029	
								1.24
6-62-23 Isleton	92693	5/20	7	215	46	268	.0029	
6-62-25 Lower Mokelumne	83435	5/19	0	218	51	269	.0032	
6-62-26 Old River	89500	5/17	0	76	17	94	.0011	
1984								
6-62-27 Courtland	62604	6/11	39	293	-	332	.0053	
6-62-37 Port Chicago	23558	6/29	30	158	-	188	.0080	
								.0060
6-62-31 Port Chicago	18442	6/29	17	56	-	73	.0040	
								.89
6-62-28 SF Mokelumne	41371	6/12	17	195	-	212	.0049	
6-62-29 Ryde	44818	6/13	14	142	-	155	.0034	
6-62-32 NF Mokelumne	59808	6/14	9	213	-	222	.0036	
6-62-33 Old River	64896	6/15	0	31	-	31	.0005	
6-54-52 Golden Gate	48677	7/25	57	949	-	1006	.0206	
6-54-51 Port Chicago	50152	7/23	68	771	-	839	.0167	
								.81

Appendix 13 (continued)

1985

6-62-40 Courtland	10901	5/10	16	-	-	-	-
6-62-39 Courtland	14753	5/10	3	-	-	-	-
6-62-38 Courtland	54457	5/10	51	-	-	-	-
6-62-41 Courtland	20550	5/10	12	-	-	-	-
6-62-34 SF Mokelumne	100386	5/7	23	-	-	-	-
6-62-35 Ryde	107161	5/11	120	-	-	-	-
6-62-36 NF Mokelumne	101237	5/9	80	-	-	-	-
6-62-42 Old River	105289	5/8	35	-	-	-	-
6-62-44 Golden Gate	47518	5/14	60	-	-	-	-
6-62-45 Port Chicago	48143	5/13	53	-	-	-	-

1/ All CWT salmon used in this experiment were from Feather River Hatchery (FRH) unless noted otherwise.
2/ See Appendix for methodology for adjusted Delta survival for 1969-1971.
3/ CNFH is abbreviated for Coleman National Fish Hatchery.

Appendix 14. Migration rates of CWT salmon released in the Upper Sacramento River, Delta, and San Francisco Bay and recovered by trawl at Chipps Island and at the Golden Gate Bridge from 1978 to 1987.

Year	Release Site	CWT Code	Release Date	Date 1st Fish Caught	Peak Catch	Date last Fish Caught	Miles Between Release & Recovery sites	Migration Rate miles/day
				CHIPPS ISLAND				
1978	Sacramento	6-62-2	6/6	-	-	-	60	-
1979	Sacramento	6-62-5	6/5	6/10	6/12	6/25	60	8.5
1980	Sacramento	6-62-8	6/2&3	6/6	6/8	6/27	60	10.9
	Sacramento	6-62-11	6/4&5	6/8	6/16	6/23	60	5.2
1981	Sacramento	6-62-14	6/2	6/10	6/10	6/10	60	7.5
1982	Sacramento	6-62-18	5/12	5/15	5/15	6/9	60	20
	Sacramento	6-62-20	5/11	5/14	5/19	6/17	60	7.5
	Sacramento	6-62-21	6/4	6/8	6/13&6/14	6/17	60	6.3
1983	Courtland	6-62-24	5/16	5/19	5/26	6/10	34	3.4
	Isleton	6-62-23	5/20	5/22	5/25	6/7	21	4.2
	Lower Mokelume	6-62-25	5/19	5/24	5/27	6/15	26	3.2
	Old River	6-62-26	5/17	5/22	5/27	6/10	38	3.8
	Battle Cr.	6-60-36&37	6/2	6/7	6/7	6/24	287	57.4
	Red Bluff	6-60-34&35	6/2	6/7	6/7	6/21	246	49.2
	Knights Landing	6-60-32&33	6/2	6/5	6/6	6/21	95	23.7
1984	Courtland	6-62-27	6/11	6/14	6/17	6/28	34	5.7
	Ryde	6-62-29	6/13	6/16	6/20	6/28	28	4.0
		6-42-9						
	NF Mokelumne	6-62-32	6/14	6/18	6/20	7/3	36	6
	SF Mokelumne	6-62-28	6/12	6/16	6/18	6/26	42	7
	Old River	6-62-33	6/15	6/20	6/20&6/21	6/27	38	6.9
1985	Courtland	6-62-39-41	5/10	5/14	5/16	5/25	34	5.7
	Ryde	6-62-35	5/11	5/14	5/16	5/25	28	5.6
	NF Mokelumne	6-62-36	5/9	5/14	5/15	5/27	36	6
	SF Mokelumne	6-62-34	5/7	5/14	5/14	5/25	42	6
	Old River	6-62-42	5/8	5/11	5/12	5/25	38	9.5
	Battle Creek	5-41-4	5/14	5/20	5/22	5/25	287	35.8
		5-40-4						
		5-39-4						
		5-6-16						
		H5-1-5						
	Below Red Bluff Diverson Dam	5-43-4	5/14	5/21	5/22	5/31	246	30.8
		5-42-4						
		5-9-47						
		H5-1-6						
	Princeton	5-9-48	5/15	5/20	5/22	5/24	166	23.7
		5-9-49						
		H5-1-7						

Appendix 14 (Cont.)

1986	Courtland	6-62-43	5/27	5/31	6/3	6/10	34	4.9
	Ryde	6-62-48	5/30	6/1	6/3	6/13	28	7.0
	NF Mokelume	6-62-47	5/29	6/2	6/4&6/5	6/18	36	5.5
	SF Mokelume	6-62-46	5/28	6/1	6/7	6/18	42	4.2
	Old River	6-62-49	5/31	6/2	6/3	6/8	38	12.7
	Battle Creek	H5-4-2 H5-4-3	5/13	5/20	5/20	5/27	287	41.0
	Below Red Bluff Diversion Dam	H5-4-4 H5-4-5	5/13	5/20	5/21	6/1	246	30.8
	Princeton	H5-4-6 H5-4-7	5/14	5/19	5/20	5/27	166	27.7
1987	Courtland (x-channel gates closed)	6-62-53 6-62-54	4/28	5/1	5/3	5/14	34	6.8
	Courtland (x-channel gates opened)	6-62-56&57	5/1	5/4	5/7	5/22	34	5.7
	Ryde (gates closed)	6-62-55	4/29	5/2	5/3	5/12	28	7.0
	Ryde (gates opened)	6-62-58	5/2	5/5	5/6	5/16	28	7.0
	Battle Creek	5-18-39	5/12	5/18	5/19	5/21	287	41.0
	Below Red Bluff Diversion Dam	5-18-40	5/13	5/19	5/19	5/22	246	41.0
	Princeton	5-18-41	5/14	5/19	5/19	5/19	166	33.2
				GOLDEN GATE				
1983	Port Chicago	6-62-30	5/21	5/27	5/31	6/7	40	4.0
1984	Port Chicago	6-62-31 6-62-37	6/29	7/2	7/3	7/9	40	8.0
	Port Chicago	6-54-51	7/23	7/26	7/28	7/31	40	6.7
1985	Port Chicago	6-62-45	5/13	5/17	5/22	5/29	40	4.4
1986	Port Chicago	6-62-51	67/2	6/5	6/6	6/18	40	10.0

Appendix 15. Methodology for adjusting survival rates for marked salmon released at Rio Vista (1969-1971) instead of Port Chicago.

In 1969, 1970 and 1971 experiments were designed for other purposes so planting sites were not exactly the same as used in 1978-1982 (Sacramento and Port Chicago). Yet, they provided an opportunity to obtain additional information about survival of young salmon migrating through the Delta. To ultilize this data and allow comparisons, we standardized all survival estimates to the reach between Sacramento and Port Chicago. This standardization consisted of calculating the instantaneous mortality rate per mile between the release points using:

$$Z = \frac{-\log_e S_d}{d}$$

Where: Z = instantaneous mortality rate (where an "instant" =1 mile), and

S_d = estimated survival over distance d between the release points (d measured in miles).

The mortality rate per mile (Z) and the total distance between Sacramento and Port Chicago (69 miles) were then used to estimate survival between these two points using $S = e^{-Z(69 \text{ miles})}$.

Standardizations were unable to be made for those groups released at Courtland (1983 and 1984) because this group had estimates of survival of greater than one (1983).

We also were unable to standardize all of our survival estimates to the reach between Courtland and Port Chicago because we had measured survival between Sacramento and Port Chicago in 1982 of over one. Thus releases made at Courtland were not corrected for the differences in distance, but were noted in the text as being bias high.

Appendix 16

Smolt Survival Estimates
Based on Midwater Trawl Marked Smolt Recoveries

Methodology

Our Delta survival index, $\hat{S}_T$, was based on the recovery of coded wire tagged (CWT) smolts (released between 1978 and 1986) recaptured by daily mid-water trawling at Chipps Island or the Golden Gate. $\hat{S}_T = R/MT(0.0078)$ where R is the number of trawl recaptures from CWT salmon released upstream of the trawling site; M is the number of marked salmon released, and T is a factor accounting for the portion of time sampled when the marked fish were passing the trawl site (time between capture of first and last marked fish). The value (0.0078) equals the trawl width (9.1 m) divided by the width of the channel at Chipps Island (1200 m). Another fraction was used for the Golden Gate trawl site. The survival index based on the midwater trawl has the advantage of providing results at the end of the emigration season while the survival estiamte based on ocean tag recoveries requires waiting a minimum of three years.

Appendix 17. Data for the index of Delta survival (S_T) when marked fish from Feather River Hatchery are released in the North Delta (Sacramento or Courtland) and recovered in the midwater trawl sampling at Chipps Island.

Year and Release Location	Tag Code	Release Date	Number Released	Number Recovered at Chipps Is.	Percent Time Sampled	Survival Index (S_T)	Rio Vista Flow	Temp at Release °F	Size at Release (in mm)	Percent Diverted at Walnut Grove
78 Sac	6-62-02	6/5,6/6	162,253	0		0	6481	73	91	65
79 Sac	6-62-05	6/2-6/5	160,157	50	.0953	.42	6055	68	75	65
80 Sac	6-62-08	6/5	98,586	34						
80 Sac	6-62-11	6/10	84,642	31						
Total			183,228	65	.1361	.34	15215	62	96	27
81 Sac	6-62-14	6-4	71,932	1						
81 Sac	6-62-17	6-4	68,318	0						
Total			140,249	1	.1111	.0083	4718	76	90	70
82M Sac	6-62-20	5-11	85,885	100	.1021	1.48	30538	70	76	23
82J Sac	6-62-21	6-5	60,822	31	.1028	.64	22931	68	76	25
83 C	6-62-24	5-16	96,706	92	.1111	1.06	47750	60	79	23
84 C	6-62-27	6-11	62,604	37	.1175	.61	9067	66	82	63
85 C	6-62-38	5-6	54,457	23		.395				
85 C	39	5-6	14,753	2		.126				
85 C	40	5-6	10,901	3		.258				
85 C	41	5-6	20,550	9		.410				
Total			107,162	37	.1388	.32	7201	64	78	65
86 C	6-62-43	5-28	104,000	39	.1387	.35	7738	73	81	64
87 C1/	6-62-53	4-28	49,781	32		.60				
87 C1/	6-62-54	4-28	50,521	39		.72				
Total			100,302	71	.1383	.67	5160	66.5	81	69
87C2/	6-62-56	5/1	49,083	20		.39				
87C2/	6-62-57	5/1	51,836	23		.42				
Total			100,919	43	.1383	.40	5273	66.5	79	69

Sac = Sacramento
C = Courtland

1/ Cross channel gates at Walnut Grove (diversion point) closed.
2/ Cross channel gates at Walnut Grove opened.

Appendix 18. Mean length and size difference of tagged salmon, released at Sacramento, Courtland, Rio Vista and Port Chicago, used for our Delta survival estimate (S_o) derived from ocean tag recoveries.

Year	Release Site	Mean length (mm)	Difference in mean length (mm)
1969	Sacramento	89.7	1.0
	Rio Vista	88.7	
1970	Sacramento	86.5	0.0
	Rio Vista	86.5	
1971	Sacramento	86.0	8.5
	Rio Vista	77.5	
1978	Sacramento	90.9	1.8
	Port Chicago	89.1	
1979	Sacramento	74.5	-8.7
	Port Chicago	83.2	
1980	Sacramento	96.9	9.1
	Port Chicago	87.8	
1981	Sacramento	89.7	-0.4
	Port Chicago	90.1	
1982	Sacramento	76	4.0
	Port Chicago	72	
1983	Courtland	79	-3.0
	Port Chicago	82	
1984	Courtland	82	0
	Port Chicago	82	

Appendix 19. Temperatures in hatchery truck and receiving waters in degrees Fahrenheit experienced by tagged salmon, released at Sacramento, Courtland, Rio Vista and Port Chicago, used in survival estimates (S_o) based on ocean tag recoveries.

Year	Planting Site	Truck Temp.	Rec. Water Temp.	Temp. Diff.
1969	Sacramento	- -	65.5*	- -
	Rio Vista	- -	68.6	- -
1970	Sacramento	- -	70.5*	- -
	Rio Vista	- -	66.8	- -
1971	Sacramento	- -	61.3*	- -
	Rio Vista	- -	60.0	- -
1978	Sacramento	57	72.6	15.6
	Port Chicago	57	67.8	10.8
1979	Sacramento	54	68	14
	Port Chicago	- -	- -	
1980	Sacramento	52	62	10
	Port Chicago	57	70	13
1981	Sacramento	57	76	18
	Port Chicago	55	75	20
1982	Sacramento	56	68	12
	Port Chicago	57	67	10
1983	Courtland	52	60	8
	Port Chicago	50	67	17
1984	Courtland	57	66	9
	Port Chicago	59	72	13

* Temperatures were taken at Freeport.

Appendix 20

AN EVALUATION OF HISTORIC SPRINGTIME TEMPERATURES IN THE SACRAMENTO RIVER WITH PARTICULAR EMPHASIS ON EMIGRATING JUVENILE SALMON

In May and June, water temperatures in the Sacramento River rise and can reach levels which are too high for late emigrating juvenile salmon. In many areas of the river, temperatures are almost always above 18°C during juvenile salmon emigration and they sometimes reach the lethal level of 24°C (75°F) defined by Brett, Clark, and Shelbourne 1982. Water temperatures above 18°C (64.4°F) are usually considered undesirable for chinook juveniles and, unless food is abundant, temperatures of that or even lower levels will slow growth. Kelley et al. (1985) estimated that there was sufficient food in the upper reach of the lower American River to make water temperatures of 18°C or below acceptable. The fact that juvenile salmon emigrating down the lower Sacramento feed primarily on terrestrial insects that accidentally fall into the river (Sasaki 1966) and that benthic invertebrate production, usually the prime source of food, is poor there leads us to suspect that food may be scarce. If this is true, survival of juvenile salmon in the Sacramento River is likely to be reduced when temperatures exceed 18°C.

Reuter and Mitchell (1987) have conducted an analysis of seasonal and long-term (1965-1985) changes in temperature at a number of locations throughout the Sacramento River system.

These included Red Bluff, Butte City, Grimes, Sacramento, and Freeport. The most important findings from their analyses are:

1. Water temperature warms rapidly as spring advances from April through June.

2. Water temperature frequently exceeds desirable levels for juvenile salmon in May and early June and, at times, rises above lethal levels.

3. These suboptimal temperatures do not only occur during exceptionally low flow years. Values of >18°C were found over a wide range of streamflows.

5. Temperature generally decreases with streamflow in a logarithmic fashion; however, the variation of temperature at any given flow can be high (i.e., 3-6 degrees Celsius).

6. Since 1976, average May and June water temperatures have been 1-4 degrees Celsius higher than they were during the previous decade (1965-1975).

Figures 1-3 show the long-term patterns of Sacramento River temperature at Grimes, Sacramento (above the confluence of the American River), and Freeport. The data for Grimes and Freeport is presented as bi-weekly (14 day) averages for the

Appendix 20 (Cont.)

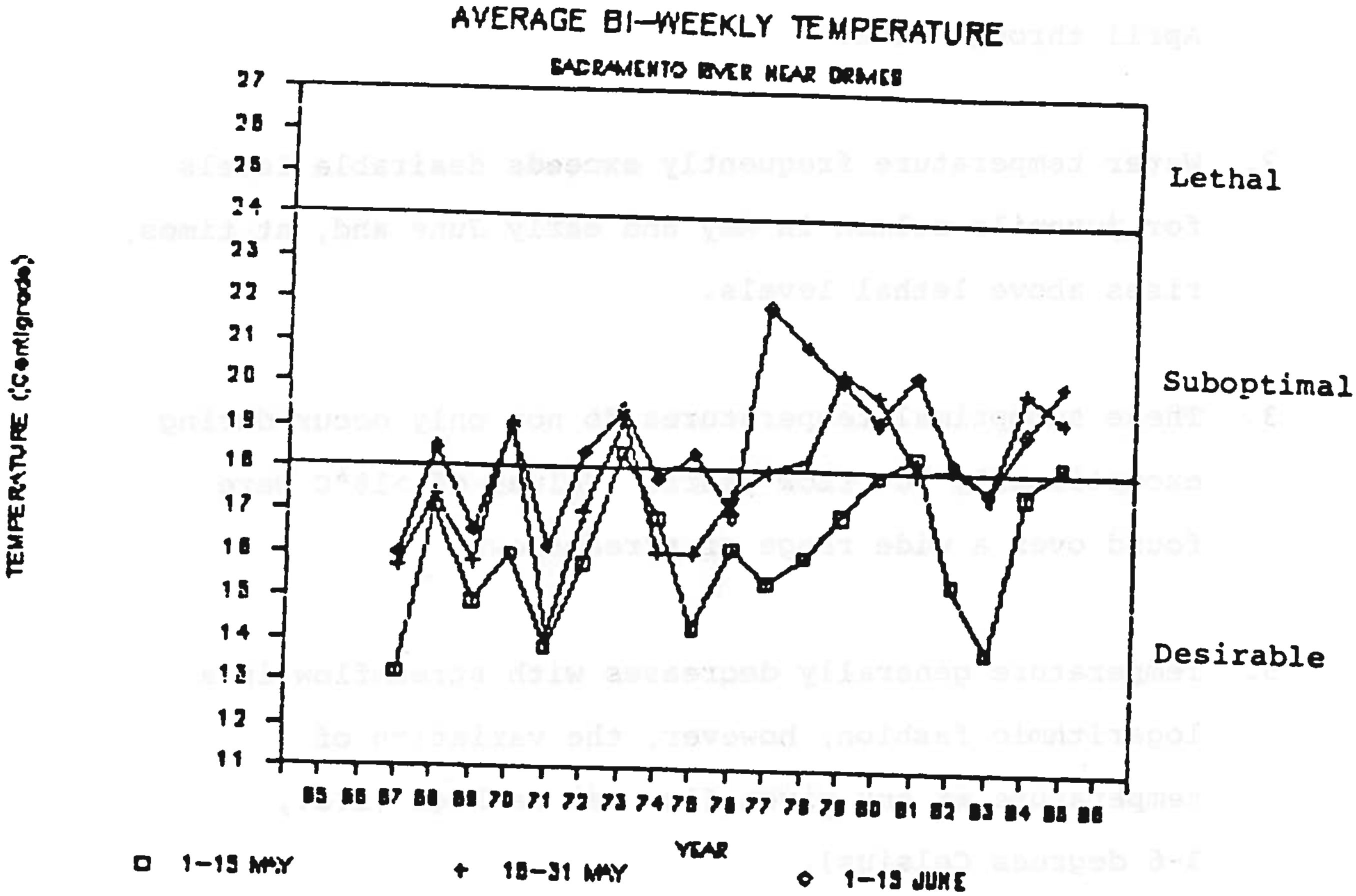


Figure 1. Average bi-weekly (14 day) temperature (°C) in the Sacramento River near Grimes (RM 118) from 1 May to 15 June. Values were calculated from daily measurements between 1967-1985 at the US Geological Survey gauging station (#11390500). Temperatures below 18°C are considered desirable for emigrating juvenile salmon, temperatures between 18°-24°C are suboptimal, and temperatures greater than 24°C are lethal. Note the abundance of suboptimal values in late-spring since 1976.

Appendix 20 (Cont.)

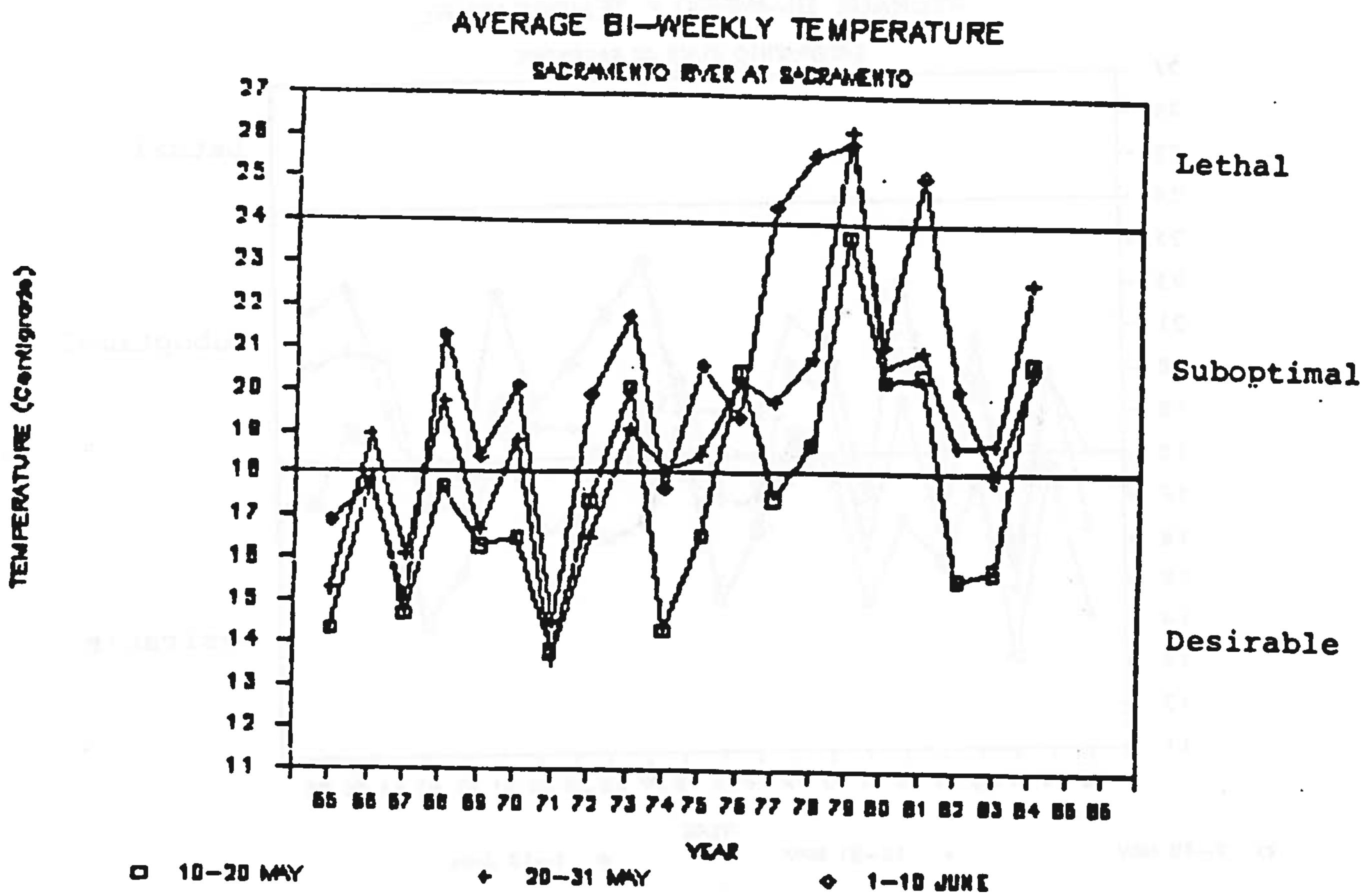


Figure 2. Average bi-weekly (14 day) temperature (°C) in the Sacramento River at Sacramento immediately above the confluence of the American River (RM 60) from 10 May to 10 June. Values are taken from Dettman and Kelley (1986) and were 'reconstructed' using temperature and flow measurements made by the City of Sacramento in the American River and the Sacramento River immediately downstream of the confluence. Temperature are typically in the suboptimal range by mid-May and since 1976, values have frequently reached lethal levels by early June. Differences between pre- and post 1976 temperatures are greatest at this station.

Appendix 20 (Cont.)

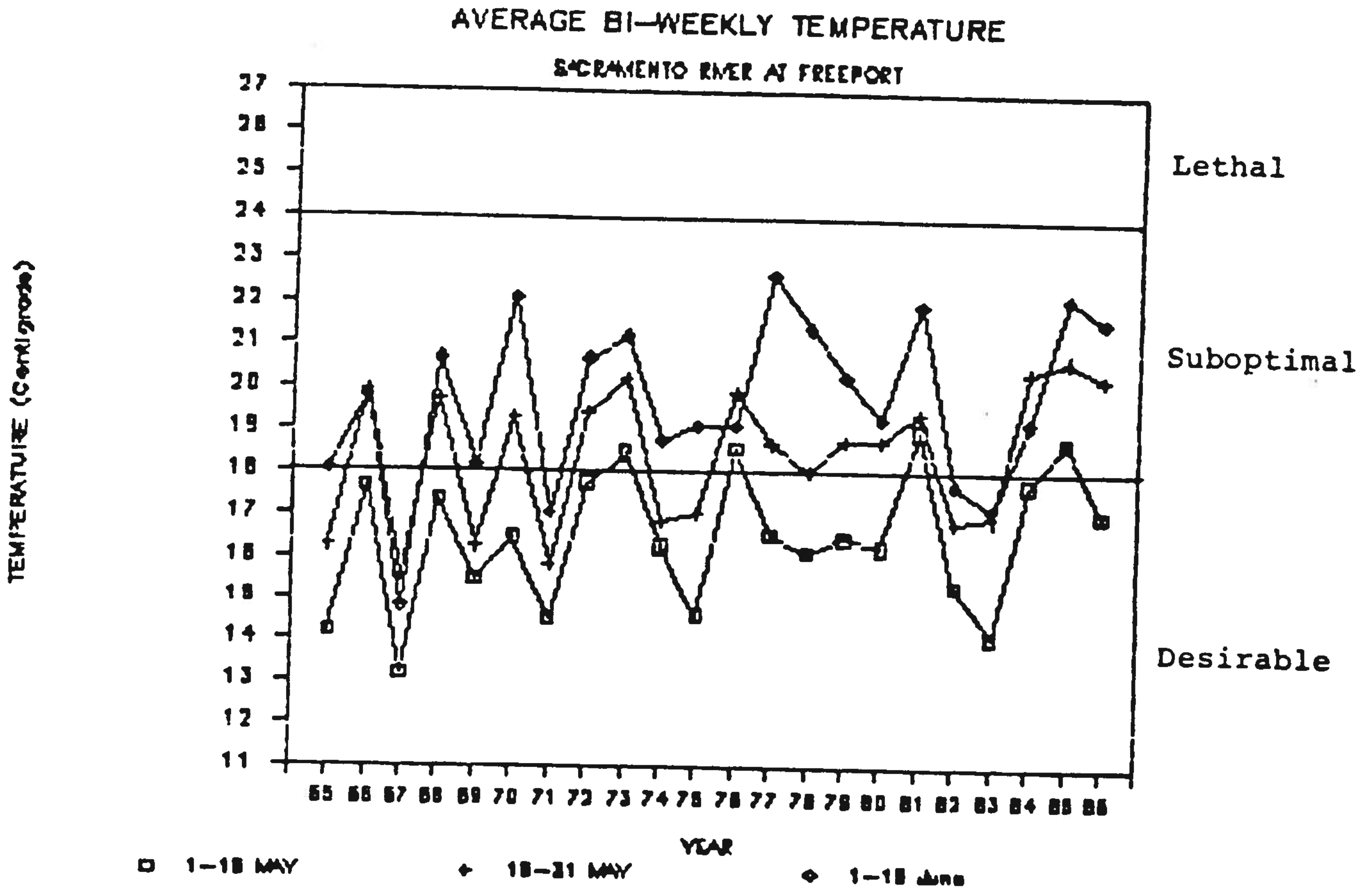


Figure 3. Average bi-weekly (14 day) temperature (°C) in the Sacramento River at Freeport (RM 48) from 1 May to 15 June. Values were calculated from daily measurements between 1965-1986 at the US Geological Survey gauging station (#11447650). Similar to Sacramento, temperatures at Freeport were frequently suboptimal in mid-late May and early June. At no time did the bi-weekly values reach lethal levels.

1 May-15 June period when most emigrants are passing through, and was taken from the USGS record of daily maximum and minimum temperatures at these sites. Average daily temperature taken by the City of Sacramento in the American River and the Sacramento River (downstream of the confluence) was used to "reconstruct" the 10-day average temperature record immediately above the confluence (Dettman and Kelley 1986).

In general, water temperature at all three stations increased as the season progressed from May to mid-June. The average rise in temperature during this 6-week period was 2.5-3.0 degrees Celsius with increases of >4 degrees Celsius not uncommon. The magnitude of this seasonal increase was not determined solely by streamflow.

The most striking feature of this long-term data is that throughout the ~20-year period of record, temperatures are frequently suboptimal for juvenile salmon survival and that these less desirable values are found throughout a large segment (~75 miles) of the river. At Grimes (RM 118), temperatures in early June are almost always greater than 18°C; whereas, in early May, temperatures rarely exceed this level. In late May and early June, the frequency at which values exceed 18°C was significantly higher since 1976. At no time did the temperature at Grimes reach the lethal level of 24°C.

As water flows downstream, it is warmed significantly by solar radiation, air temperature, tributary discharge, and warm return irrigation water from agricultural activities in the Valley. Water temperatures at Sacramento have often exceeded desirable levels for juvenile salmon by mid-May, and since 1976 have occasionally done that by early May. In fact, seasonal warming has increased water temperatures to lethal levels by early June in some recent years (e.g., 1977, 1978, 1979, 1981). Of all the Sacramento River stations with long-term data, the post 1976 warming is most pronounced (2.5-3.0 degree Celsius increase) at this location. Indeed, since 1977 it is uncommon to find mid-May through early June temperatures which drop below 18°C.

The long-term records at Freeport (RM 48), ~12 miles below the City of Sacramento, indicate that undesirable temperatures for juvenile salmon are reached by mid-May in nearly half the years. Temperatures during June are almost always above 18°C, but lethal levels during June are extremely rare. The increase in water temperatures since 1976 are less evident here than at upstream stations. In addition to the factors that regulate temperature upstream, temperatures in this reach are sometimes influenced by large contributions of cooler American River water as well as the cool, strong evening and night winds from the Delta.

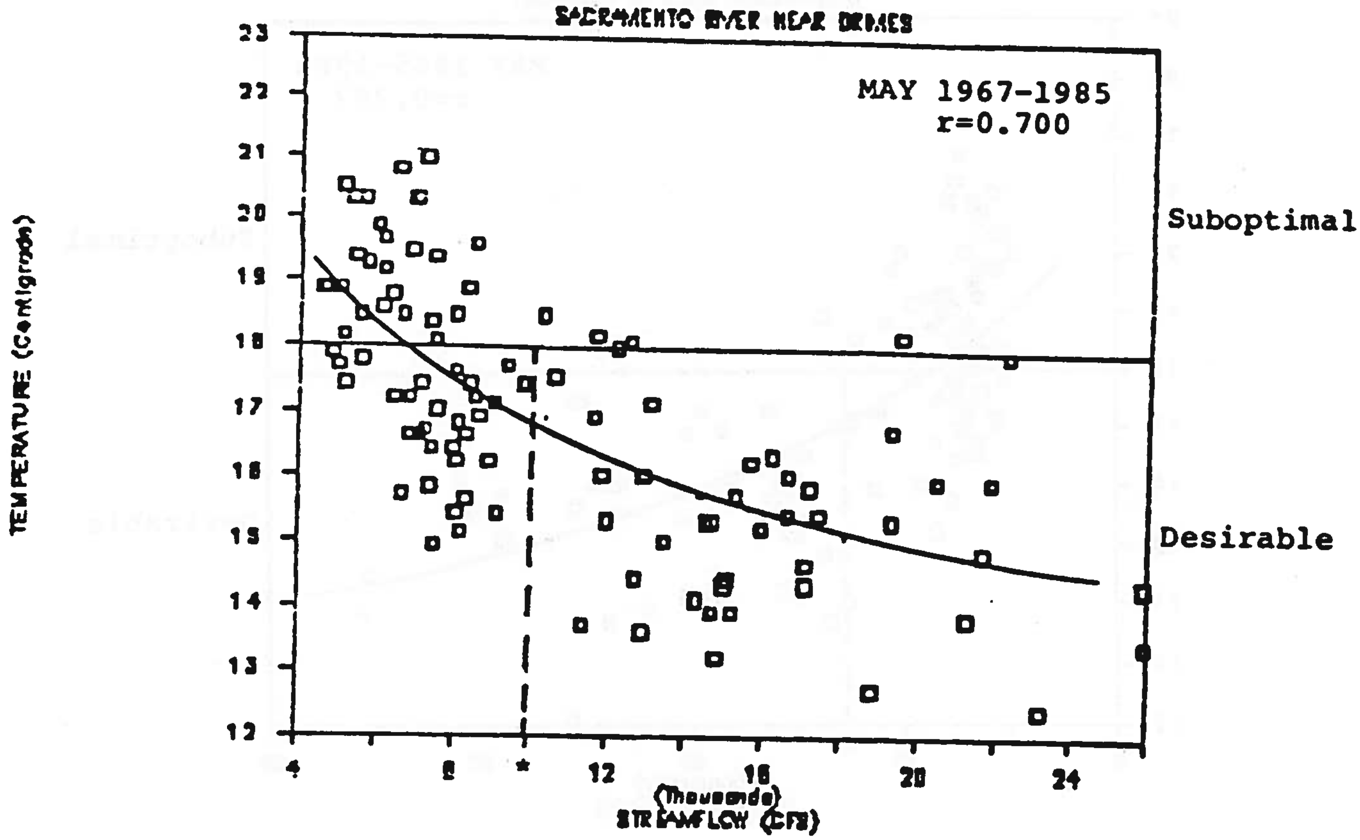
Appendix 20 (Cont.)

During the spring, water temperature in the Sacramento River is influenced by the magnitude of streamflow; and, in general, these two variables are inversely related (i.e., higher flow leads to lower temperature). For most locations, the relationship between 5-day average temperature and flow during May and June is best described by a negative logarithmic equation. This is to be expected since change in temperature for a given change in flow tends to become smaller at higher flows. The relationship between flow and temperature is presented in Figures 4 and 5 for May and June at Grimes and Freeport. A detailed description of these relationships at all five long-term data sites is given in Reuter and Mitchell (1987) and we use these two sites here only as examples.

While a general relation between temperature and flow is apparent, it is also clear that there is a considerable amount of variation in temperature at any given flow. At high flows this variation was largely due to the higher average temperatures in only a few years (i.e., 1982 and 1983 relative to 1967). However, more years of data are represented by low flows; and the explanation for the variation in temperature, under these reduced flow conditions, is not clear at this point. While air temperature certainly has some effect, there is only a poor correlation between air and water temperatures (r=0.306). In a multiple correlation analysis of the effect of flow and air temperature, the latter could explain only 12% to 13% of the variation in water temperature at both Grimes and Red Bluff.

Figures 4 and 5. Flow versus temperature relationships for the Sacramento River near Grimes and at Freeport in May and June. Each point represents a 5-day average, and data for the entire 18-20-year period of record is included. In all cases, the relationship was best described by a logarithmic equation, and the line of best fit along with the associated correlation coefficient (r) is given. The dotted vertical line extending downward from the 18°C level represents the flow which historically has been needed to ensure river temperatures of less than 18°C. In May, temperatures less than 18°C have been achieved at lower flows, but because of the large variation in temperature at these reduced flows, it is difficult to accurately predict whether or not values will be suboptimal for juvenile salmon survival solely on the basis of discharge. During June, the occurrence of 18°C temperatures at low flows have been considerably less.

FLOW VERSUS TEMPERATURE RELATIONSHIP



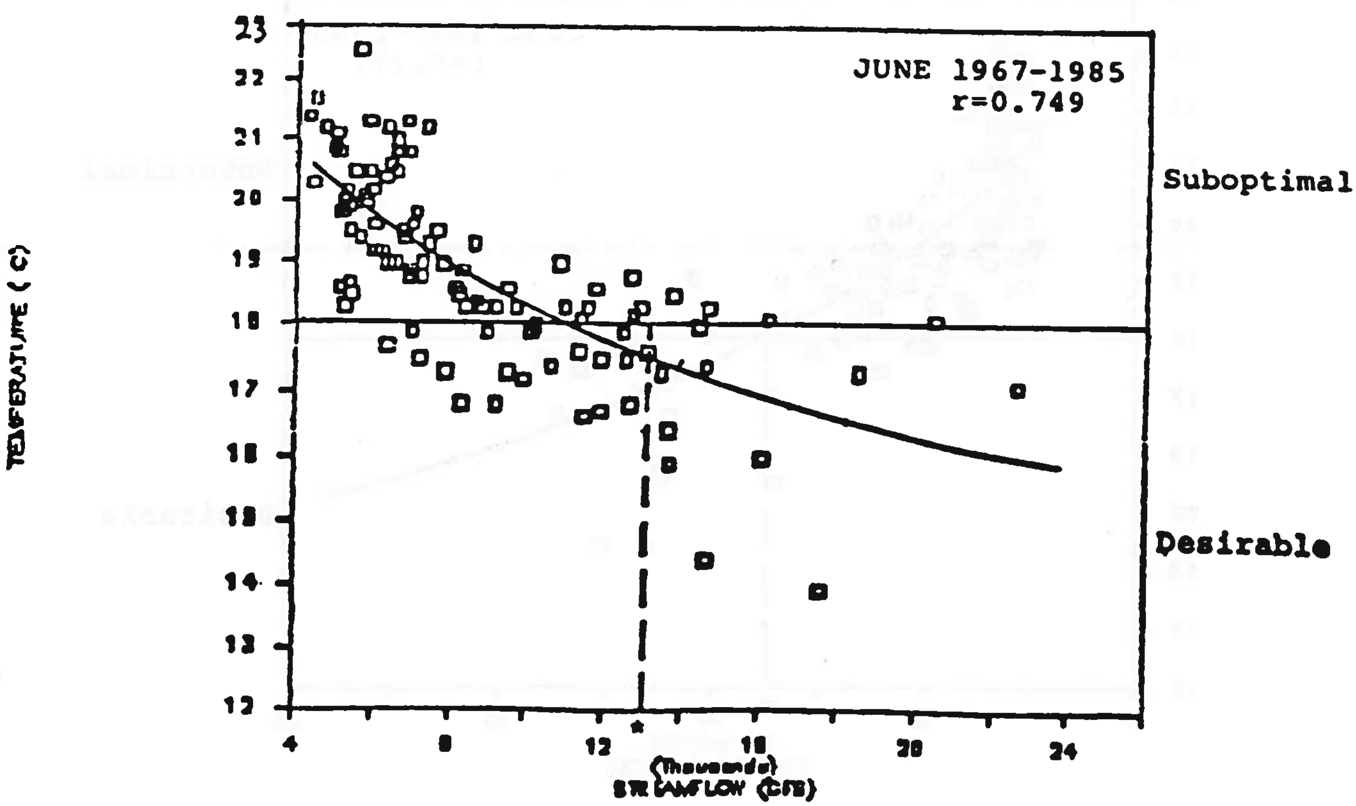


Figure 4. Legend on preceeding page

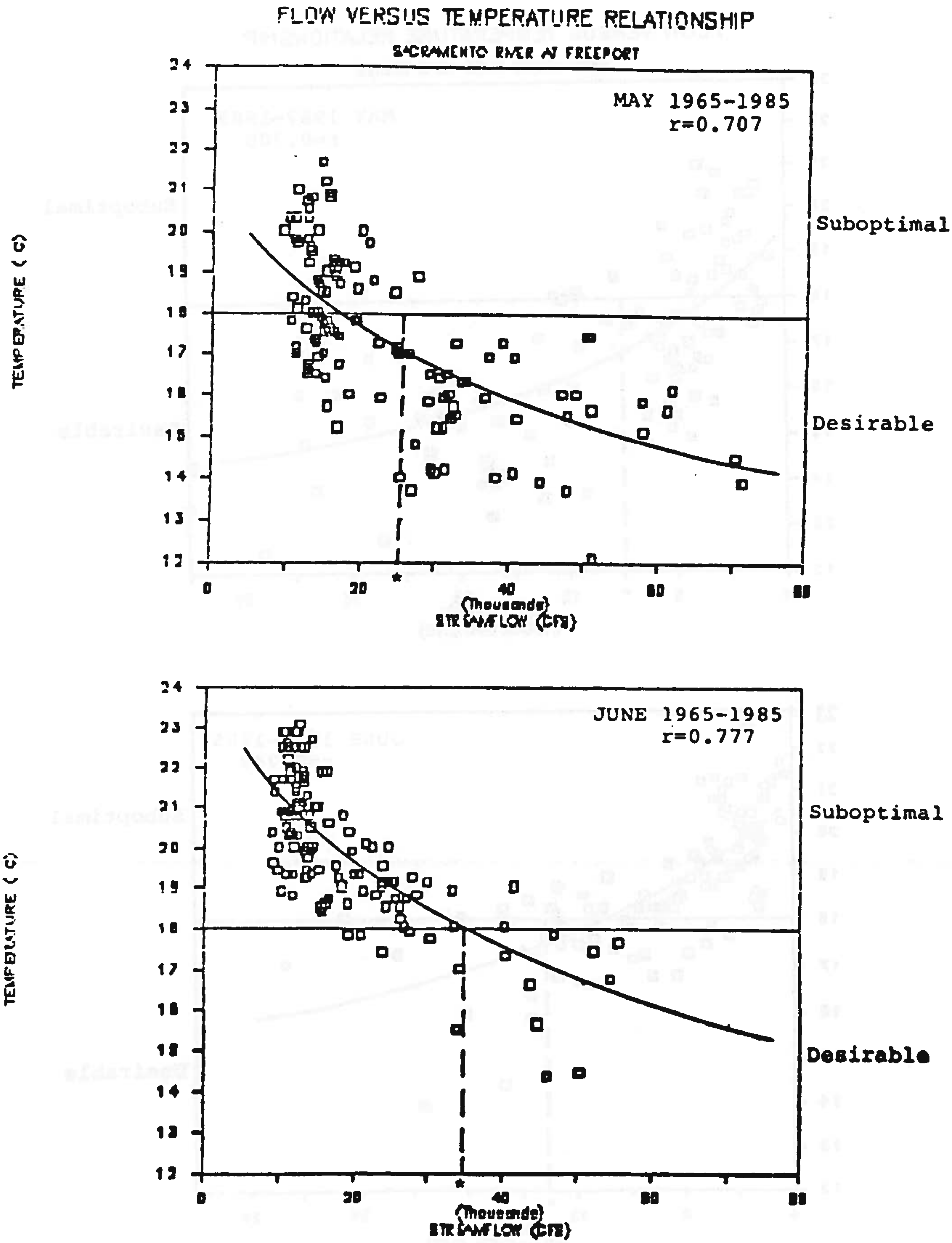


Figure 5. Legend on preceeding page

The historical data indicates that at Grimes, flow should exceed ~10,000 cfs in May and ~13,000 cfs in June to ensure that temperature does not exceed 18°C. Downstream, flows at Freeport would need to exceed ~25,000 cfs in May and ~33,000 cfs in June. This is not to imply that temperatures of <18°C cannot be achieved at lower flows. This is especially true in May where temperatures are below 18°C approximately 50% of the time when flows are less than those stated above. In June, the likelihood of encountering temperatures below 18°C at flows less than those stated above are reduced at Grimes and almost negligible at Freeport.

At this point, it appears as though the major mechanism for reducing temperatures in June to less than 18°C is to increase flow. In May, however, the data indicates that it is possible to have desirable temperatures for juvenile salmon at lower flows. A profitable approach would be to determine the cause(s) of the variation in temperature at lower flows. If it is found that controllable factors such as reservoir operations and return irrigation water are important, this would provide some basis for hope that water temperature could be maintained at more desirable levels without having to depend solely on augmenting flow.

Appendix 21. Equations used to derive the percent diverted on the Sacramento River at Walnut Grove and the percent diverted on the San Joaquin River at Mossdale and estimates of flow at Rio Vista on the Sacramento River. Equations were obtained from California Department of Water Resources DAYFLOW.[1/]

$$\text{Percent Diverted} = \frac{\text{X-Channel + Georgiana Slough}}{\text{I Street - (Steamboat + Sutter)}}$$

Steamboat Slough = .192 x I Street - 150 cfs

Sutter Slough = .182 x I Street - 800 cfs

Georgiana Slough + X Channel =

When gates are open: .293 x I Street + 2090 cfs

When gates are closed: .133 x I Street + 829 cfs

Rio Vista flow = I Street - (Georgiana + X Channel) + Yolo Bypass

Percent diverted off of mainstream San Joaquin into Old River at Mossdale: estimates based on DWR exhibit 50, San Joaquin flow at Vernalis and total exports from DAYFLOW.

1/ Also see DWR exhibit 50 for source of equations.

Appendix 22. Release, recovery and survival data (S_T) for Feather River coded wire tagged (CWT) fish released throughout the Delta and recovered in the midwater trawl at Chipps Island, for 1983-1987. No interior Delta releases were made before 1983.

Year	Tag Code	Release Site	Release Date	Number Released	Number Recovered	Percent Time Sampled	Delta Indices	Size at Release(mm)	Temp at Release °F
1983	6-62-23	Isleton	5/20	92,693	95	10	1.33	81	61°
	6-62-25	Lower Mokelumne	5/19	83,435	73	10	1.13	75	63°
	6-62-26	Old River	5/17	89,500	23	10	.33	76	63°
1984	6-62-29	Ryde	6/13	44,818	37	10	1.05	77	66°
	6-62-32	NF Mokelumne	6/14	59,808	24	10	.51	79	67°
	6-62-28	SF Mokelumne	6/12	41,371	33	12	.86	77	67°
	6-62-33	Old River	6/15	64,896	9	11	.16	73	75°
1985	6-62-35	Ryde	5/11	107,162	88	14	.77	78	66°
	6-62-32	NF Mokelumne	5/9	101,238	30	14	.28	77	65°
	6-62-34	SF Mokelumne	5/7	100,386	25	14	.23	75	64°
	6-62-42	Old River	5/8	91,200	20	14	.21	84	68°
1986	6-62-48	Ryde	5/28	101,320	74	14	.68	81	74°
	6-62-47	NF Mokelumne	5/29	101,949	32	11	.36	74	72°
	6-62-46	SF Mokelumne	5/30	102,965	24	12	.26	77	68°
	6-62-49	Old River	5/31	98,869	24	14	.23	78	74°
1987	6-62-55	Ryde (gates closed)	4/29	51,103	46	14	.85	79	67°
	6-62-85	Ryde (gates opened)	5/2	51,008	47	14	.88	80	64°

Appendix 23. Annual number of salmon salvaged at CVP/SWP Fish Facilities (April through June).[1/]

Year	CVP	SWP	Total
1970	378,420	29,815	408,235
1971 (highest)	404,972	15,432	420,404
1972	267,156	76,447	343,603
1973	169,392	32,785	202,177
1974	242,060	125,335	367,395
1975	101,920	21,333	123,253
1976	100,632	18,330	118,962
1977 (lowest)	9,168	5,202	14,370
1978	9,576	14,741	24,317
1979	103,731	98,314	202,045
1980	151,202	68,549	219,751
1981	63,337	74,523	137,860
1982	163,414	173,422	336,836
1983	192,412	38,581	230,993
1984	170,325	113,471	283,796
1985	108,114	133,309	241,423
1986	302,848	400,567	703,415

1/ See CDFG exhibit 17 entitled "Entrainment Losses".

Appendix 24a. Expanded recoveries of spray-dyed fish released in Upper Old River and San Joaquin River and recovered at the State (SWP) and Federal (CVP) Fish Facilities in 1985.

	State			Federal		
Day	Upper Old River (Red)	San Joaquin at Dos Reis (Yellow)	Unmarked	Upper Old River (Red)	San Joaquin at Dos Reis (Yellow)	Unmarked
Apr 29	0	0	194	60	0	284
Apr 30	1	0	563	14684	0	3676
May 1	1206	0	1494	6016	52	2576
May 2	2836	0	2860	2140	4	2624
May 3	1864	0	1048	724	14	1088
May 4	2188	40	4524	362	10	978
May 5	1140	45	2593	284	0	844
May 6	658	12	1788	218	92	802
May 7	496	260	2444	136	156	972
May 8	304	420	1904	129	141	847
May 9	219	502	1827	40	136	2788
May 10	80	308	3968	216	276	5472
May 11	256	220	4592	258	306	5502
May 12	152	520	5288	168	88	2076
May 13	116	152	2452	112	80	2068
May 14	148	454	5420	48	32	1506
May 15	6	108	2100	34	22	730
Total	11670	3041	45059	25629	1409	34833

Appendix 24b. EXPANDED DAILY RECOVERIES OF CODED-WIRE TAGGED SALMON RELEASED IN THE STANISLAUS, OLD AND SAN JOAQUIN RIVERS, IN 1986 AT THE FEDERAL FISH FACILITY (CVP).

DATE	ADIPOSE CLIPPED	UNMARKED	LOWER STANISLAUS	UPPER OLD RIVER	LOWER OLD RIVER	SAN JOAQUIN RIVER
15-Apr	0	202	0	0	0	0
16-Apr	26	284	0	0	0	0
17-Apr	70	522	0	0	0	0
18-Apr	128	600	0	0	0	0
19-Apr	116	1,018	0	0	0	0
20-Apr	94	772	0	0	0	0
21-Apr	60	1,024	0	0	0	0
22-Apr	492	5,420	0	0	0	0
23-Apr	648	7,968	0	0	0	0
24-Apr	546	8,262	0	0	0	0
25-Apr	404	5,534	0	0	0	0
26-Apr	292	3,160	0	0	0	0
27-Apr	188	3,599	0	0	0	0
28-Apr	412	4,958	0	0	0	0
29-Apr	476	5,448	0	0	0	0
30-Apr	1,044	7,908	428	0	0	0
01-May	3,088	7,600	2,328	0	0	0
02-May	1,580	8,896	552	0	0	0
03-May	932	3,994	196	0	0	0
04-May	524	4,094	158	0	0	0
05-May	368	5,440	100	0	0	0
06-May	262	3,122	80	0	0	0
07-May	188	2,740	24	0	0	0
08-May	162	3,236	28	0	0	0
09-May	164	3,192	36	0	0	0
10-May	236	5,304	146	0	0	0
11-May	188	3,964	60	0	0	0
12-May	98	2,366	18	0	0	0
13-May	42	2,724	6	0	0	0
14-May	128	3,820	16	0	0	0
15-May	62	2,438	18	0	0	0
16-May	52	1,436	0	0	0	0
17-May	16	1,520	4	0	0	0
18-May	68	1,900	8	0	0	0
19-May	72	3,284	0	0	0	0
20-May	68	3,464	0	0	0	0
21-May	28	1,876	4	0	0	0
22-May	28	1,612	0	0	0	0
23-May	77	2,503	0	0	0	0
24-May	60	1,856	0	0	0	0
25-May	6	2,284	0	0	0	0
26-May	48	1,596	20	0	0	0
27-May	72	4,732	0	0	0	0
28-May	142	3,548	0	0	0	0
29-May	16	3,456	0	0	0	0
30-May	12,120	4,008	0	10,260	0	12
31-May	44,940	7,520	0	40,596	0	200
01-Jun	16,776	5,628	0	14,772	60	72
02-Jun	2,456	1,260	0	472	1,512	96

Appendix 24b. EXPANDED DAILY RECOVERIES OF CODED-WIRE TAGGED SALMON RELEASED IN THE STANISLAUS, OLD AND SAN JOAQUIN RIVERS, IN 1986 AT THE FEDERAL FISH FACILITY (CVP). (CONTINUED)

DATE	ADIPOSE CLIPPED	UNMARKED	LOWER STANISLAUS	UPPER OLD RIVER	LOWER OLD RIVER	SAN JOAQUIN RIVER
03-Jun	1,056	6,792	0	156	624	0
04-Jun	1,140	8,716	0	128	740	60
05-Jun	236	1,480	0	48	156	24
06-Jun	80	992	0	0	56	0
07-Jun	56	318	0	12	16	0
08-Jun	16	202	0	0	8	0
09-Jun	16	278	0	0	4	0
10-Jun	20	168	0	12	4	0
11-Jun	8	252	0	0	0	0
12-Jun	24	246	0	0	0	0
13-Jun	0	120	0	0	0	0
14-Jun	20	364	0	0	12	0
15-Jun	0	56	0	0	0	0
16-Jun	0	656	0	0	0	0
17-Jun	0	120	0	0	0	0
18-Jun	0	144	0	0	0	0
TOTALS	92,735	193,996	4,230	66,456	3,192	464

Appendix 24c. EXPANDED DAILY RECOVERIES OF CODED-WIRE TAGGED SALMON RELEASED IN THE STANISLAUS, OLD AND SAN JOAQUIN RIVERS, IN 1986 AT THE STATE FISH FACILITY (SWP).

DATE	ADIPOSE CLIPPED	UNMARKED	LOWER STANISLAUS	UPPER OLD RIVER	LOWER OLD RIVER	SAN JOAQUIN RIVER
16-Apr	0	1,044	0	0	0	0
17-Apr	24	568	0	0	0	0
18-Apr	124	1,392	0	0	0	0
19-Apr	416	2,320	0	0	0	0
20-Apr	886	5,166	0	0	0	0
21-Apr	364	3,892	0	0	0	0
22-Apr	224	3,004	0	0	0	0
23-Apr	732	10,584	0	0	0	0
24-Apr	576	6,132	0	0	0	0
25-Apr	894	15,246	0	0	0	0
26-Apr	868	12,942	0	0	0	0
27-Apr	1,712	21,816	0	0	0	0
28-Apr	384	8,780	0	0	0	0
29-Apr	664	8,316	8	0	0	0
30-Apr	936	11,332	0	0	0	0
01-May	3,142	7,648	2,116	0	0	0
02-May	3,688	7,168	2,880	0	0	0
03-May	2,184	9,408	852	0	0	0
04-May	2,322	11,232	792	0	0	0
05-May	984	6,792	384	0	0	0
06-May	612	5,388	300	0	0	0
07-May	612	3,360	276	0	0	0
08-May	364	3,360	132	0	0	0
09-May	472	4,288	72	0	0	0
10-May	156	4,864	60	0	0	0
11-May	323	3,413	14	0	0	0
12-May	212	2,506	76	0	0	0
13-May	178	5,546	178	0	0	0
14-May	160	5,428	80	0	0	0
15-May	280	4,272	180	0	0	0
16-May	276	3,308	116	0	0	0
17-May	460	4,808	88	0	0	0
18-May	336	10,636	124	0	0	0
19-May	78	6,934	36	0	0	0
20-May	220	3,608	196	0	0	0
21-May	144	2,002	0	0	0	0
22-May	128	2,988	0	0	0	0
23-May	27	3,230	0	0	0	0
24-May	64	6,202	0	0	0	0
25-May	116	3,944	0	0	0	0
26-May	132	3,526	0	0	0	0
27-May	0	1,036	0	0	0	0
28-May	40	956	0	0	0	0
29-May	0	1,328	0	0	0	0
30-May	12	3,582	0	0	0	0
31-May	0	0	0	0	0	0
01-Jun	2,584	8,880	0	1,540	0	240
02-Jun	2,120	3,860	0	1,590	90	180
03-Jun	2,820	8,100	0	1,200	660	600

Appendix 24c. (Cont.) EXPANDED DAILY RECOVERIES OF CODED-WIRE TAGGED SALMON RELEASED IN THE STANISLAUS, OLD AND SAN JOAQUIN RIVERS, IN 1986 AT THE STATE FISH FACILITY (SWP).

DATE	ADIPOSE CLIPPED	UNMARKED	LOWER STANISLAUS	UPPER OLD RIVER	LOWER OLD RIVER	SAN JOAQUIN RIVER
04-Jun	1,140	7,320	0	0	660	360
05-Jun	1,200	9,300	0	0	540	600
06-Jun	1,020	3,840	0	60	300	240
07-Jun	60	2,340	0	60	0	0
08-Jun	1,080	7,160	0	0	720	300
09-Jun	0	2,460	0	0	0	0
10-Jun	180	3,348	0	180	0	0
11-Jun	186	4,400	0	12	20	0
12-Jun	16	545	0	0	8	0
13-Jun	240	744	0	0	0	0
14-Jun	300	720	0	0	0	0
15-Jun	240	840	0	0	0	0
TOTALS	39,712	319,152	8,960	4,642	2,998	2,520

APPENDIX 24d. EXPANDED DAILY RECOVERIES OF CODED-WIRE TAGGED SALMON RELEASED IN THE TUOLUMNE, OLD AND SAN JOAQUIN RIVERS, IN 1987 AT THE FEDERAL FISH FACILITY (CVP).

DATE	ADIPOSE CLIPPED	UNMARKED	LOWER TUOLUMNE	UPPER OLD RIVER	SAN JOAQUIN RIVER
04/17/87	0	98	0	0	0
04/18/87	336	576	264	0	0
04/19/87	1,284	528	1,064	0	0
04/20/87	588	540	372	0	0
04/21/87	1,164	624	180	0	0
04/22/87	636	609	86	0	0
04/23/87	108	432	12	0	0
04/24/87	288	1,896	84	0	0
04/25/87	48	774	36	0	0
04/26/87	24	384	12	0	0
04/27/87	48	456	0	0	0
04/28/87	16,584	3,012	168	13,704	0
04/29/87	2,856	1,728	84	2,136	48
04/30/87	1,020	1,956	24	714	38
05/01/87	432	2,172	45	305	0
05/02/87	252	1,536	36	144	24
05/03/87	300	2,388	0	120	144
05/04/87	321	2,212	0	132	108
05/05/87	468	3,170	32	70	277
05/06/87	496	5,304	44	101	258
05/07/87	506	4,024	18	128	254
05/08/87	226	3,042	8	20	138
05/09/87	180	4,152	0	24	156
05/10/87	24	1,176	0	0	24
05/11/87	72	726	0	0	48
05/12/87	0	132	0	0	0
05/13/87	12	264	0	0	12
05/14/87	0	108	0	0	0
05/15/87	0	72	0	0	0
05/16/87	0	156	0	0	0
05/17/87	0	324	0	0	0
05/18/87	0	168	0	0	0
05/19/87	0	315	0	0	0
05/20/87	0	387	0	0	0
05/21/87	0	282	0	0	0
05/22/87	0	276	0	0	0
TOTAL	28,273	45,999	2,569	17,598	1,529

APPENDIX 24e. EXPANDED DAILY RECOVERIES OF CODED-WIRE TAGGED SALMON RELEASED IN THE TUOLUMNE, OLD AND SAN JOAQUIN RIVERS, IN 1987 AT THE STATE FISH FACILITY (SWP).

DATE	ADIPOSE CLIPPED	UNMARKED	LOWER TUOLUMNE	UPPER OLD RIVER	SAN JOAQUIN RIVER
04/17/87	8	204	0	0	0
04/18/87	12	748	0	0	0
04/19/87	402	717	342	0	0
04/20/87	3,374	1,142	2,584	0	0
04/21/87	1,064	730	802	0	0
04/22/87	605	611	450	0	0
04/23/87	520	1,032	282	0	0
04/24/87	521	1,886	331	0	0
04/25/87	274	1,158	160	0	0
04/26/87	104	683	32	0	0
04/27/87	138	1,446	90	24	0
04/28/87	912	2,328	116	580	0
04/29/87	2,146	1,931	82	1,731	4
04/30/87	1,415	1,771	112	1,001	0
05/01/87	972	3,582	138	714	27
05/02/87	780	2,634	12	570	18
05/03/87	472	1,716	8	232	78
05/04/87	588	2,142	12	312	96
05/05/87	840	1,542	84	438	108
05/06/87	1,341	3,494	48	425	306
05/07/87	2,604	1,668	0	757	475
05/08/87	812	4,228	0	72	1,283
05/09/87	486	2,778	0	108	576
05/10/87	348	1,656	0	12	270
05/11/87	624	3,408	0	168	312
05/12/87	1,536	19,644	0	60	300
05/13/87	244	5,276	0	0	1,026
05/14/87	450	8,990	0	0	184
05/15/87	368	11,374	0	0	270
05/16/87	180	1,692	0	0	368
05/17/87	0	8,760	0	0	0
05/18/87	180	2,880	0	0	0
05/19/87	0	2,940	0	0	0
05/20/87	0	180	0	0	0
05/21/87	0	240	0	0	0
05/22/87	0	840	0	0	0
TOTAL	24,320	108,051	5,685	7,204	5,701

Appendix 25. Annual estimates of adult chinook spawning escapement in the San Joaquin River and in the Central Valley from 1957 to 1986.[1]

Year	San Joaquin	Central Valley
1957	8.5	88.4
1958	39.6	234.7
1959	28.3	369.4
1960	53.1	416.6
1961	2.0	229.4
1962	1.7	189.2
1963	1.3	262.3
1964	7.8	266.9
1965	6.7	169.8
1966	6.4	184.4
1967	20.9	131.2
1968	7.0	173.4
1969	50.7	311.8
1970	30	177.0
1971	40	177.9
1972	12	91.0
1973	6.5	205.5
1974	3.7	191.7
1975	5.8	145.8
1976	3.5	157.8
1977	.6	134.6
1978	2.3	125.3
1979	4.0	152.0
1980	5.0	130.0
1981	14.0	156.0
1982	14.0	141.0
1983	11.6	101.7
1984	41.1	163.1
1985	60.9	273.0
1986	16.1	214.2

1/ Source for adult escapement estimates between 1957 to 1969 was from Dave Dettman per. comm., Don Kelley and Associates, estimates between 1970 to 1984 were from PFMC, 1986, estimates of 1984 and 1985 from Bob Reavis, CDFG per. comm.

Appendix 26

FRY REARING - GENERAL METHODOLOGY

Since 1978, the abundance and distribution of fall-run chinook fry (defined as 30 to 70 mm fish) has been measured throughout the Estuary (Figure 26-1) with weekly (Delta), and biweekly or monthly (Bay) seine surveys from January to April. A 50 x 4 foot, 1/4 inch mesh beach seine with 4 x 4 foot bag were used. Our index of salmon fry abundance is the number of salmon per seine haul. One seine haul was made at each site per sampling day. Sites were diverse (boat launch ramps, sand beaches, etc.) but were sampled in a consistent manner and covered about 50 to 100 feet of shoreline. Schaffter (1980) found that salmon fry are most abundant along the shore during their rearing phase. The number of sampling sites by region varied: north Delta (14 stations), central Delta (10 stations), San Francisco Bay (8 stations since 1980) and the Sacramento River above the Delta (7 stations) to Colusa, California.

Since 1980, the survival and movements of chinook fry produced at Coleman National Fish Hatchery were assessed by marking them with coded wire half tags (CW1/2T) removing the adipose fin for external identification, and releasing them in the Estuary and upper Sacramento River below Red Bluff Diversion Dam

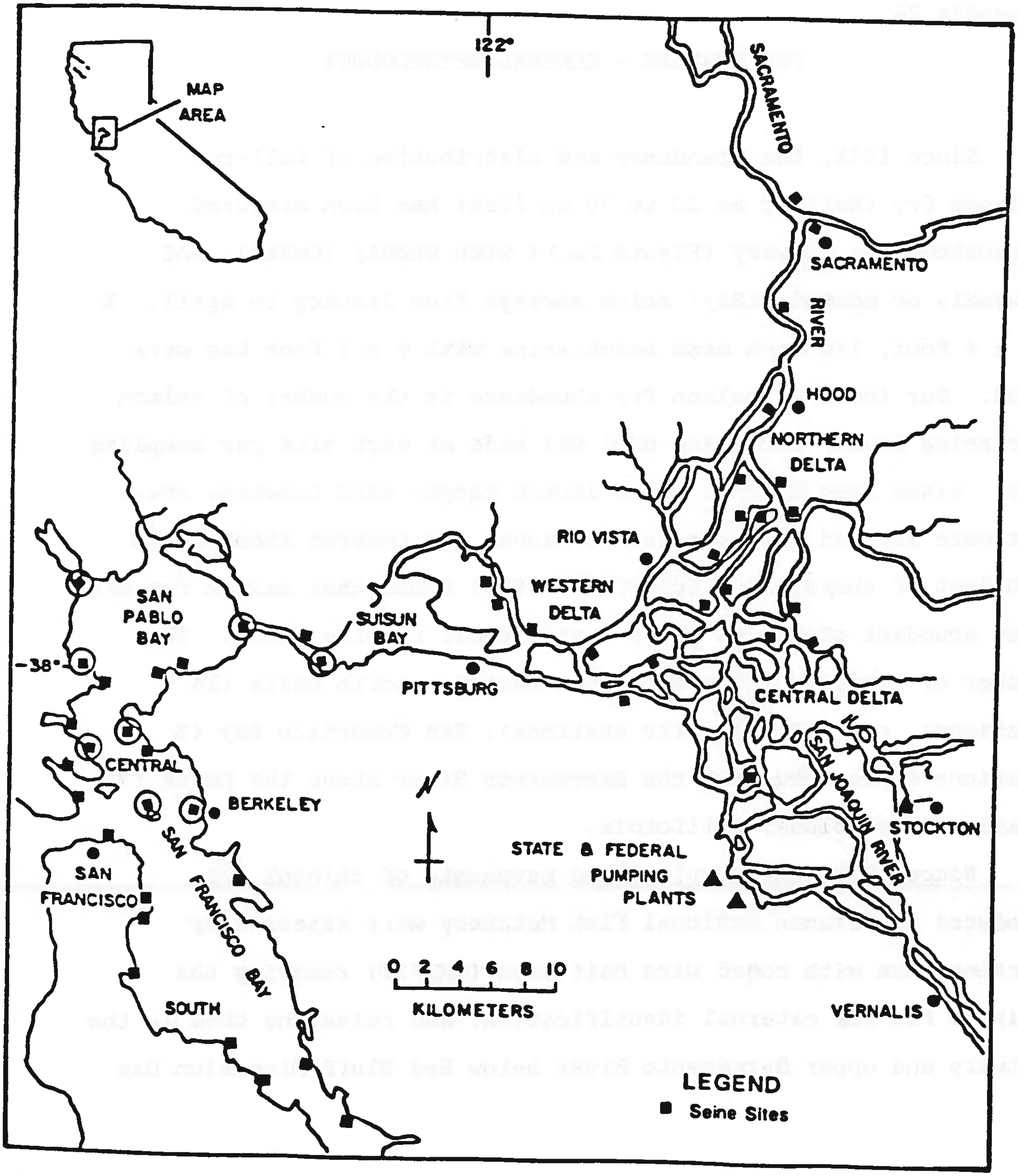


Figure 26-1. Beach seine recovery sites for salmon fry studies. Stations circled are those used to estimate the average catch per seine haul of fry in San Francisco Bay from 1977 to 1986 (Table 6-1). These and the other stations in San Francisco Bay were used to determine abundance and distribution by station in 1980-1986 (Figure 6-1).

(Figure 2-2). Recoveries of CW1/2T fry were made by seine collections, midwater trawl surveys, the salvage process at the CVP/SWP fish facilities, and subsequently through the ocean sport and commercial fishery (as adults).

Appendix 27. Mean monthly fry abundance indices (fish/haul) based on beach seine catches in the Lower Sacramento River, North and Central Delta and San Francisco Bay from 1978 to 1986.

Location	Year	Month	Index $\bar{x}$ # Fish/Haul
Lower Sacramento	1981	1	-
		2	36.5
		3	15.86
		4	2.86
	1982	1	24.7
		2	10.2
		3	12.0
		4	43.7
	1983	1	40.29
		2	18.83
		3	46.83
		4	15.86
	1984	1	27.89
		2	9.22
		3	4.50
		4	1.14
	1985	1	1.00
		2	2.86
		3	3.00
		4	1.79
	1986	1	19.54
		2	47.80
		3	30.30
		4	19.00

Appendix 27 (Cont.)

Location	Year	Month	Index $\bar{x}$ # Fish/Haul
North Delta	1978	1	15.25
		2	19.95
		3	22.38
		4	7.49
	1979	1	23.54
		2	50.78
		3	45.58
		4	12.78
	1980	1	13.65
		2	19.75
		3	24.5
		4	10.8
	1981	1	5.4
		2	20.5
		3	9.5
		4	12.0
	1982	1	9.17
		2	19.3
		3	37.0
		4	16.6
	1983	1	39.57
		2	34.9
		3	48.2
		4	32.0
	1984	1	13.60
		2	15.08
		3	11.96
		4	2.98
	1985	1	1.95
		2	16.53
		3	18.71
		4	2.29
	1986	1	30.47
		2	35.04
		3	34.62
		4	16.18

Appendix 27 (Cont.)

Location	Year	Month	Index $\bar{x}$ # Fish/Haul
Central Delta	1979	1	-
		2	5.67
		3	7.26
		4	2.68
	1980	1	2.59
		2	3.59
		3	2.30
		4	.86
	1981	1	.2
		2	3.6
		3	3.4
		4	1.9
	1982	1	1.37
		2	5.8
		3	8.4
		4	3.2
	1983	1	9.72
		2	11.6
		3	10.2
		4	3.0
	1984	1	3.22
		2	5.71
		3	4.77
		4	.5
	1985	1	.29
		2	.47
		3	4.26
		4	0
	1986	1	6.74
		2	16.54
		3	13.21
		4	3.18

Appendix 27 (Cont.)

Location	Year	Month	$\bar{x}$ # Fish/Haul Index
San Francisco Bay	1980	1	13.0
		2	3.1
		3	1.5
		4	.2
	1981	1	--
		2	.3
		3	0
		4	1.3
	1982	1	1.5
		2	.2
		3	2.3
		4	.4
	1983	1	1.7
		2	2.6
		3	2.6
		4	.6
	1984	1	.3
		2	0
		3	0
		4	0
	1985	1	0
		2	0
		3	0
		4	0
	1986	1	.1
		2	5.8
		3	.3
		4	.3

Appendix 28. Recoveries of CWl/2T fry during the Bay and Delta beach seining survey (January through April) 1980 to 1987.

Release Site	Recovery Site
1980	
Red Bluff (1)	Sacramento Sites; American River (1)
	San Joaquin and Interior Delta sites; None recovered
Clarksburg (23)	Sacramento Sites; Clarksburg (10), Isleton (4), Brannon Is. (3), Stump Beach (1)
	San Joaquin and Interior Delta Sites; Cross channel (1), Terminous (1), Edos (1), West Is. (1)
Berkeley (4)	San Francisco Bay sites; Treasure Island (4)
1981	
Red Bluff (3)	Sacramento Sites; Steamboat Slough (1), Isleton (1)
	San Joaquin and Interior Delta Sites; Antioch (1)
Tehema Colusa Fish Facility (2)	Sacramento Sites; Discovery Park (1), American River (1)
	San Joaquin and Interior Delta Sites; None recovered
Isleton (24)	Sacramento Sites; Isleton (18), Koket (1), Brannon Island (3), Stunip Beach (1), Sherman Island (1)
	San Joaquin and Interior Delta Sites; None recovered
Lower Mokelumne (9)	Sacramento Sites; Brannon Island (3)
	San Joaquin and Interior Delta Sites; Woodward Island (2), Venice Island (2), Terminous (1) Kings Island (1)

Appendix 28 (Cont.)

Release Site	Recovery Site
1982	
Red Bluff (6)	Sacramento Sites; Discovery Park (5) Ryde (1)
	San Joaquin and Interior Delta Sites; None Recovered
Isleton (74)	Sacramento Sites; Isleton (49), Rio Vista (8), Stamp Beach (5)
	San Joaquin and Interior Delta sites; Antioch (1)
Lower Mokelumne (3)	Sacramento Sites; Brannon Island (1), Sherman Island (2)
	San Joaquin and Interior Delta Sites; None Recovered
Berkeley (2)	San Francisco Bay; Hunters Pt. (1), Coyote Pt. (1)
1983	
Courtland (33)	Sacramento Sites; Ryde (14), Brannon Island (6), Stump Beach (1), Sherman Island (1)
	San Joaquin and Interior Delta; Georgiana Sl (9), B&W (1)
Isleton (81)	Sacramento Sites; Isleton (74), Stump Beach (5) Brannon Island (2)
	San Joaquin and Interior Delta; None recovered
Old River (2)	Sacramento Sites; Brannon Is. (2)
	San Joaquin and Interior Delta; None recovered
Lower Mokelumne (1)	Sacramento Sites; None recovered.
	San Joaquin and Interior Delta; Edo's (1)

Appendix 28 (Cont.)

Release Site	Recovery Site
1984	
Courtland (35)	Sacramento Sites; Ryde (12), Isleton (3), Stump Beach (3), Brannon Is. (2)
	San Joaquin and Interior Delta; Georgiana Sl. (10), Terminous (3), SF Mokelumne (1), Antioch (1)
Ryde (65)	Sacramento Sites; Ryde (34) Stump Beach (18), Isleton (6), Rio Vista (3), Brannon Is. (3), Sherman Is (1)
	San Joaquin and Interior Delta; None Recovered
NF Mokelumne (8)	Sacramento Sites; Sherman Is. (1)
	San Joaquin and Interior Delta; Terminous (4), B&W (3)
SF Mokelumne (25)	Sacramento Sites; Brannon Is. (1)
	San Joaquin and Interior Delta; Terminous (18), SF Mokelumne (6)
1985	
Courtland (22)	Sacramento Sites; Isleton (7), Ryde (3), Clarksburg (2), Stump Beach (1)
	San Joaquin and Interior Delta; Edo's (4), Georgiana Slough (3), B&W (2)
Ryde (30)	Sacramento Sites; Ryde (12), Isleton (10), Rio Vista (4), Stump Beach (4)
	San Joaquin and Interior Delta; None recovered.
NF Mokelumne (35)	Sacramento Sites; None recovered
	San Joaquin and Interior Delta; SF Mokelumne (31), X-Channel (4)
SF Mokelumne (44)	Sacramento Sites; None recovered
	San Joaquin and Interior Delta; SF Mokelumne (42), X-Channel (1), B&W (1)

Appendix 28 (Cont.)

Release Site	Recovery Site
1986	
Courtland (6)	Sacramento Sites; Isleton (2), Stump Beach (1), Brannon Island (1)
	San Joaquin and Interior Delta; B&W (2)
Ryde (9)	Sacramento Sites; Brannon Is. (6), Isleton (2), Stump Beach (1)
	San Joaquin and Interior Delta; None recovered.
1987	
Courtland (0)	None recovered.

Appendix 29. Unexpanded number of CW1/2T salmon fry recovered at the CVP and SWP Fish Facilities and an estimation of sampling effort for these fish from 1980 to 1987.

Year	Number Recovered	Release Site	Number Released	Estimated Effort
1980	0	Red Bluff	91,800	Routine
	0	Clarksburg	90,480	Monitoring (2 samples/day)
1981	3	Lower Mokelumne	90,989	"
	4	Isleton	86,865	"
		Red Bluff	82,924	
1982	0	Lower Mokelumne	85,319	"
	0	Isleton	83,756	
	0	Red Bluff	85,426	"
1983	0	Lower Mokelumne	93,327	"
	0	Isleton	93,323	
	0	Old River	96,257	
1984	8	Ryde	92,232	4/25 to 5/5
	3	SF Mokelumne	45,036	sampling every
	5	NF Mokelumne	42,165	2 hours at
	1	Red Bluff	91,738	the State Fac.
	0	Courtland	96,617	
1985	9	Courtland	103,186	4/29 to 5/15
	11	Ryde	99,733	sampling every
	6	NF Mokelumne	51,145	2 hours at
	5	SF Mokelumne	50,002	both facilities
	2	Red Bluff	101,468	5/16 to 6/13 7 days conducted handling and trucking sampling at SWP
1986	0	Courtland	104,792	4/15 to 6/15
	0	Ryde	105,383	samples every
	0	Red Bluff	51,426	2 hours both facilities
1987	7	Courtland (81)1/	51,789	4/17 to 5/22
	1	Red Bluff (12)1/	54,280	samples every
	1	Battle Creek (8)1/	54,393	2 hours both facilities

1/ Numbers expanded by time sampled.

Appendix 30. Ocean tag recovery rates from CW1/2T salmon fry released in the Upper Sacramento River, Delta and San Francisco Bay, 1980-1987.

Year Released	CWT Code	Number Released	Release Location	Release Date	Size at Release (in mm)	Number of Expanded Recoveries in Ocean by Age 2	3	4	Total Recoveries (Expanded)	Recovery Rate
1980	H5-3-1	25,617	Below RBDD	2/29/80	47	31	149	23	204	.007963
	H5-3-2	22,574	"	2/29/80	47	9	147	5	160	.007088
	H5-3-5	21,786	"	3/12/80	45	28	89	24	142	.006517
	H5-3-6	21,836	"	3/12/80	45	6	128	8	142	.006503
	Total	91,813							648	.007057
	H5-2-6	22,215	Clarksburg	2/26/80	50	6	27	0	33	.001485
	H5-2-7	21,624	"	2/26/80	50	2	65	0	71	.003283
	H5-3-3	26,012	"	3/07/80	46	2	37	2	41	.001576
	H5-3-4	20,808	"	3/07/80	44	9	42	1	52	.002499
	Total	90,659							197	.002172
	H5-2-4	21,937	Berkeley	2/20/80	46.4	0	1	0	1	.0000455
	H5-2-5	20,726	"	2/20/80	46.4	0	0	1	1	.0000482
	Total	42,663							2	.0000468
1981	H6-1-1	39905	Below RBDD	2/06/81	41	17	38	5	59	.001478
	H6-1-5	47019	"	2/27/81	40	6	53	3	80	.001701
	Total	86924							139	.001599
	H6-1-2	40916	Isleton	2/12/81	45	1	19	0	20	.000489
	H6-1-6	45949	"	3/04/81	43	11	58	4	73	.001588
	Total	86865							93	.001070
	H6-1-3	45193	Mokelumne R.	2/20/81	44	2	11	0	13	.000287
	H6-1-7	45796	"	3/06/81	43	10	26	0	36	.000786
	Total	90981							49	.000539
	H6-1-4	49705	Berkeley	2/25/81	44	0	6	0	6	.0001207
	H6-2-1	36901	"	3/11/81	43	0	0	1	1	.0000271
	Total	86606							7	.0000808
1982	H6-2-2	41753	Below RBDD	2/05/82	44	10	150	6	166	.003975
	H6-2-6	43673	"	2/25/82	44	9	115	23	147	.003365
	Total	85426							313	.003664
	H6-2-3	43248	Isleton	2/11/82	44	12	20	2	34	.000786
	H6-2-7	40508	"	3/02/82	45	3	5	4	11	.000271
	Total	83756							45	.000537
	H6-2-4	43849	Mokelumne R.	2/17/82	43	0	3	9	17	.000387
	H6-3-2	41470	"	3/10/82	44	3	14	5	21	.000506
	Total	85319							38	.000445

Appendix 30 (Cont.)

Year Released	CWT Code	Number Released	Release Location	Release Date	Size at Release (in mm)	Number of Expanded Recoveries in Ocean by Age 2	3	4	Total Recoveries (Expanded)	Recovery Rate
	H6-2-5	40699	Berkeley	2/22/82	44	0	1	5	6	.000147
	H6-3-1	39321	"	3/08/82	44	1	0	0	1	.000025
	Total	80020							7	.000087
1983	H6-3-3	45805	Isleton	3/04/83	45	0	7	1	8	.000175
	H6-4-2	47518	"	3/29/83	49	0	26	6	32	.000673
	Total	93323							40	.000429
	H6-3-4	48541	Courtland	3/09/83W	47	0	19	0	19	.000391
	H6-4-3	48501	"	3/31/83E	51	0	41	20	61	.001257
	Total	97042							80	.000412
	H6-3-5	45960	Mokelumne	3/14/83	48	0	12	0	12	.000261
	H6-4-1	47367	"	3/24/83	49	0	34	5	40	.000844
	Total	93327							52	.000557
	H6-3-6	47677	Old River	3/17/83	49	10	35	10	55	.001153
	H6-3-7	48580	"	3/22/83	48	0	55	2	57	.001173
	Total	96257							112	.001163
1984	H6-4-4	43883	Below RBDD	3/02/84	45	25	72		97	.002210
	H6-5-4	47855	"	3/23/84	48	9	182		190	.003970
	Total	91738							287	.003128
	H6-4-5	48460	Courtland	3/05/84 W	45	10	46		56	.001155
	H6-5-3	48157	"	3/21/84 E	48	24	115		139	.002886
	Total	96617							195	.002018
	H6-4-6	45465	Ryde	3/08/84	49	2	60		62	.001363
	H6-5-2	46767	"	3/19/84	49	4	120		124	.002651
	Total	92232							186	.002016
	H6-4-7	42165	NF Mokelumne	3/12/84	50	0	40		40	.000948
	H6-5-1	45036	SF Mokelumne	3/14/84	49	0	28		28	.0006217
1985	H5-3-7	29136	Battle Crk	3/13/85	47	3				
	H5-4-1	23045	"	3/13/85	47	0				
	Total									
	H6-5-5	49155	Below RBDD	2/14/85	47	10				
	H6-6-5	52313	"	3/14/85	48	11				
	Total									
	H6-5-6	51201	Courtland	2/19/85	49	11				
	H6-6-4	51985	"	3/07/85	46	8				
	Total									

Appendix 30 (Cont.)

Year Released	CWT Code	Number Released	Release Location	Release Date	Size at Release (in mm)	Number of Expanded Recoveries in Ocean by Age 2	3	4	Total Recoveries (Expanded)	Recovery Rate
	H6-5-7	49183	Ryde	2/21/85	47	6				
	H6-6-3	50550	"	3/05/85	47	4				
	H6-6-1	50002	SF Mokelumne	2/26/85	48	6				
	H6-6-2	51145	NF Mokelumne	2/28/85	46	6				
1986	H5-7-7	51371	Battle Creek	3/18/86	50					
	H6-7-5	51426	Below RBDD	3/19/86	50					
	H6-6-7	50961	Courtland	2/27/86	45					
	H6-7-3	53831	"	3/10/86	50					
	H6-7-2	52635	Ryde	3/04/86	47					
	H6-7-4	52748	"	3/12/86	53					
1987	B5-4-13	51075	Battle Creek	3/12/87	51					
	H6-7-7	52977	Below RBDD	3/13/87	52					
	H6-7-6	48733	Courtland	3/05/87	50					

Appendix 31. Annual estimates of weight of total salmon landings in the California ocean commercial fishery by area, and estimated number of Central Valley (CV) chinook caught in the commercial ocean fishery off California for the period 1916 to 1951. Weights of total landings based on CF&G estimates. Number of Central Valley chinook salmon estimated by applying mean weights from 1952-1965 period and fractions described below (Dettman et al., 1987)

Year	California Ocean Troll Catch by Area[1] (pounds) Eureka	San Fran	Monterey	Other	Total	California Ocean Troll Catch of Central Valley Chinook by Number[2] Eureka	SanFran	Monterey	Other	Total
1916	98,353	262,889	5,230,839	135	5,592,216	2,871	16,268	407,073	7	426,218
1917	924,192	1,280,312	3,879,487	2,006	6,085,997	26,974	79,227	301,908	98	408,207
1918	1,110,611	1,928,794	2,892,876	1,065	5,933,346	32,414	119,355	225,129	52	376,950
1919	2,949,642	1,442,708	2,816,022	10	7,208,382	86,089	89,276	219,148	0	394,513
1920	3,115,381	1,459,932	1,490,877	0	6,066,190	90,926	90,342	116,023	0	297,290
1921	2,300,259	938,886	1,243,960	0	4,483,105	67,136	58,099	96,807	0	222,042
1922	2,496,841	961,317	880,129	30	4,338,317	72,873	59,487	68,493	1	200,855
1923	1,693,711	1,314,877	728,336	0	3,736,924	49,433	81,366	56,680	0	187,479
1924	1,880,342	3,617,045	877,186	0	6,374,573	54,880	223,825	68,264	0	346,969
1925	3,111,885	1,270,936	1,098,715	0	5,481,536	90,824	78,646	85,504	0	254,974
1926	2,849,509	962,413	51,755	0	3,863,677	83,166	59,555	4,028	0	146,749
1927	2,715,806	1,488,746	717,027	21	4,921,600	79,264	92,125	55,800	1	227,190
1928	2,293,832	815,815	334,654	5	3,444,306	66,948	50,483	26,043	0	143,475
1929	2,320,846	658,718	1,054,096	0	4,033,660	67,737	40,762	82,032	0	190,530
1930	2,797,993	1,008,242	279,409	6	4,085,650	81,663	62,391	21,744	0	165,798
1931	3,254,846	428,298	91,471	0	3,774,615	94,996	26,503	7,118	0	128,618
1932	2,656,788	124,010	80,884	16	2,861,698	77,541	7,674	6,295	1	91,511
1933	2,943,962	158,806	569,859	48	3,672,675	85,923	9,827	44,347	2	140,100
1934	2,824,743	818,852	286,230	0	3,929,825	82,443	50,671	22,275	0	155,389
1935	3,790,733	337,751	219,700	15	4,348,199	110,637	20,900	17,097	1	148,635
1936	3,655,768	266,440	144,924	1,020	4,068,152	106,698	16,488	11,278	50	134,514
1937	3,895,867	1,108,402	891,083	931	5,896,283	113,705	68,589	69,346	46	251,685
1938	1,868,706	94,975	199,474	183	2,163,338	54,540	5,877	15,523	9	75,950
1939	1,821,931	285,194	125,498	0	2,232,623	53,175	17,648	9,766	0	80,590
1940	3,369,492	1,177,653	613,224	34	5,160,403	98,343	72,874	47,722	2	218,940
1941	2,413,368	375,766	153,662	3,198	2,945,994	70,437	23,253	11,958	157	105,805
1942	2,255,862	1,642,051	164,931	462	4,063,306	65,840	101,611	12,835	23	180,309
1943	2,162,368	2,021,208	1,101,934	17	5,285,527	63,111	125,074	85,754	1	273,940
1944	3,792,103	2,646,714	575,579	7,452	7,021,848	110,677	163,781	44,793	365	319,615
1945	4,627,714	2,431,954	816,303	36,783	7,912,754	135,065	150,491	63,526	1,803	350,885
1946	4,545,299	2,017,703	569,350	2,120	7,134,472	132,660	124,857	44,308	104	301,928
1947	5,868,577	1,485,657	738,469	0	8,092,703	171,281	91,934	57,469	0	320,684
1948	4,033,992	1,544,479	250,906	0	5,829,377	117,737	95,573	19,526	0	232,836
1949	2,601,390	2,455,543	473,741		5,530,674	75,925	151,951	36,867	0	264,743
1950	2,217,558	4,072,973	769,705	4,715	7,064,951	64,722	252,039	59,900	231	376,891
1951	1,895,267	4,508,571	679,128	2,637	7,085,603	55,316	278,994	52,851	129	387,289

1 Sources: Years 1916-1950, Fry and Hughes (1951); 1951, CF&G Fish Bulletin No. 89.

2 Annual contributions of Central Valley chinook estimated by: 1) multiplying the weight of total salmon landings times the fraction of the 1952-1965 landings that were chinook to estimate weight of chinook landings; 2) dividing the weight of chinook landings by the average weight of chinook caught during the 1952-1965 period to estimate number of chinook landed in California; and 3) multiplying the number of fish landed times the overall fraction of fish in the fishery that were estimated to be from the Central Valley during the 1977-1986 period.

Appendix 32. Annual estimates of chinook salmon that originated in Ce[illegible]l Valley rivers and were caught in the ocean troll fisheries. Weight of all salmon and weight and numbers of chinook only are based on CF&G estimates. Contributions of CV chinook estimated by applying fractions described below (Dettman et al., 1987)

Catch Year	All Salmon (pounds x 10^6)	Chinook Only (pounds x 10^6)	California Landings of Chinook by Port Area[1] Monterey numbers	San Fran numbers	Ft Bragg numbers	Eureka numbers	C. City numbers	Total numbers	Landings of Central Valley Chinook by Port Area[2] Monterey numbers	San Fran numbers	Ft Bragg numbers	Eureka numbers	C. City numbers	CA Total numbers	Oregon numbers	Total OR + CA numbers
1952	6.5370	5.7860	81,706	215,060	96,293	47,169	34,102	474,330	77,621	171,123	47,723	7,589	6,520	310,577	30,297	340,873
1953	7.1360	6.3360	68,214	201,837	126,966	67,380	28,478	492,875	64,803	160,602	62,924	10,841	5,445	304,616	29,715	334,331
1954	8.6000	8.1680	121,539	276,472	170,508	127,512	75,033	771,064	115,462	219,989	84,504	20,517	14,346	454,818	44,367	499,185
1955	9.6570	9.2450	71,702	264,927	148,678	188,675	89,262	763,244	68,117	210,802	73,685	30,358	17,067	400,029	39,023	439,052
1956	10.2750	9.8140	102,459	253,228	246,104	245,165	111,431	958,387	97,336	201,494	121,969	39,447	21,306	481,551	46,975	528,527
1957	5.1770	4.6410	47,308	115,926	124,343	100,451	85,691	473,719	44,943	92,242	61,624	16,163	16,384	231,356	22,569	253,925
1958	3.6570	3.5760	34,513	162,742	102,461	57,031	17,968	374,715	32,787	129,494	50,780	9,176	3,435	225,673	22,014	247,687
1959	6.7690	6.5430	27,029	325,062	56,298	83,315	21,885	513,589	25,678	258,652	27,901	13,405	4,184	329,820	32,174	361,994
1960	6.2210	6.0960	75,088	231,237	55,330	100,855	77,192	539,702	71,334	183,995	27,422	16,228	14,759	313,737	30,605	344,342
1961	8.6380	8.1010	68,145	319,628	116,146	139,575	130,106	773,600	64,738	254,328	57,562	22,458	24,876	423,962	41,357	465,319
1962	6.6730	6.3020	33,814	169,951	94,652	232,368	25,434	556,219	32,123	135,230	46,910	37,388	4,863	256,514	25,023	281,537
1963	7.8480	6.8290	48,387	281,779	119,937	160,133	52,196	662,432	45,968	224,212	59,441	25,765	9,980	365,365	35,641	401,007
1964	9.4810	7.5620	37,164	239,910	189,515	194,400	25,691	686,680	35,306	190,896	93,924	31,279	4,912	356,317	34,759	391,076
1965	9.6740	8.1020	44,740	291,379	162,724	159,092	47,325	705,260	42,503	231,850	80,646	25,598	9,049	389,646	38,010	427,656
1966	9.4460	5.9790	20,177	143,029	168,840	174,814	46,715	553,575	19,168	113,808	83,677	28,128	8,932	253,713	24,750	278,463
1967	7.2420	3.8660	17,549	69,533	69,885	137,827	43,090	337,884	16,672	55,327	34,635	22,176	8,239	137,049	13,369	150,418
1968	6.9500	4.6120	58,255	167,953	100,650	115,680	29,471	472,009	55,342	133,640	49,882	18,613	5,635	263,112	25,667	288,779
1969	6.1300	4.8950	103,613	176,749	120,228	128,100	22,733	551,423	98,432	140,639	59,585	20,611	4,347	323,614	31,569	355,183
1970	6.6110	5.2690	63,732	163,097	89,143	154,496	46,180	516,648	60,545	129,776	44,179	24,858	8,830	268,189	26,162	294,351
1971	8.1100	4.9260	24,944	125,755	88,359	140,449	54,420	433,927	23,697	100,063	43,791	22,598	10,405	200,554	19,564	220,118
1972	6.4230	5.3720	40,238	189,558	114,972	108,364	39,071	492,203	38,226	150,831	56,980	17,436	7,470	270,944	26,431	297,374
1973	9.5810	7.5870	180,283	242,412	174,254	194,111	25,908	816,968	171,269	192,887	86,360	31,232	4,954	486,702	47,478	534,180
1974	8.7490	5.0480	59,895	222,785	100,130	84,442	24,310	491,562	56,900	177,270	49,624	13,587	4,648	302,029	29,463	331,492
1975	6.9100	5.7810	73,927	160,434	126,353	183,331	34,664	578,709	70,231	127,657	62,621	29,498	6,628	296,634	28,937	325,571
1976	7.7880	4.9440	99,600	138,200	115,700	165,400	21,000	539,900	94,620	109,966	57,341	26,613	4,015	292,555	28,539	321,093
1977	5.9200	5.6370	78,700	185,200	138,900	161,200	36,300	600,300	74,765	155,383	58,060	17,410	10,781	316,399	50,724	367,123
1978	6.7880	5.4920	132,800	158,200	131,900	155,200	59,600	637,700	126,160	112,322	57,640	9,312	15,675	321,109	15,443	336,552
1979	8.7460	6.8600	54,100	180,000	202,500	218,400	71,800	726,800	51,395	163,098	110,626	33,088	3,332	361,538	22,475	384,013
1980	6.0170	5.6070	82,500	211,800	130,400	131,300	32,600	588,600	78,375	175,963	82,256	21,152	5,320	363,068	20,920	383,988
1981	5.9370	5.4710	90,000	199,900	116,600	99,700	81,800	588,000	85,500	182,149	64,783	22,801	20,074	375,307	24,228	399,535
1982	7.9070	7.3660	136,700	281,800	177,200	96,000	73,600	765,300	129,865	248,350	126,787	25,526	11,371	541,900	30,639	572,539
1983	2.3020	2.0470	103,200	75,000	55,900	35,200	24,700	294,000	98,040	72,757	28,926	11,068	4,841	215,632	17,709	233,341
1984	2.9330	2.5880	54,000	167,700	49,800	14,000	14,400	299,900	51,300	100,874	17,028	4,825	3,846	177,873	21,189	199,062
1985	4.5874	4.5062	35,600	170,400	149,600	3,700	1,100	360,400	33,820	170,400	56,029	0	0	260,249	56,471	316,720
1986	7.3362	7.1456	176,600	290,000	254,800	47,400	16,900	785,700	167,770	146,612	55,551	8,163	3,673	381,769	75,143	456,912
Averages																
57-76	7.6113	6.2152	64,161	205,946	123,139	139,605	48,374	581,225	60,953	163,871	61,028	22,463	9,249	317,563	30,978	348,541
77-86	5.8474	5.2720	94,420	192,000	140,760	96,210	41,280	564,670	89,699	152,791	65,769	15,335	7,891	331,484	33,494	364,978

1 Sources: Years 1952-1965, CF&G Fish Bulletin No. 135; 1966-1975, CF&G Fish Bulletin Nos. 138, 144, 149, 153, 159, 161, 163, 166, 168; 1976-1980 PFMC (1986); 1981-1986, PFMC (1987).

2 Annual contributions of Central Valley chinook based on the recovery of coded wire tagged salmon in the commercial fisheries off California and Oregon. For the period 1977-1986 contributions for California and Oregon ports were estimated by dividing the estimated number of coded wire tag recoveries by an estimate of the fraction of CV fish with tags. For the 1952-1976 period, contributions for California ports were estimated by multiplying the number of fish landed times the overall fraction of fish from the CV. Oregon landings prior to 1977 were estimated by multiplying the ratio of Oregon to California landings of CV fish from the 1977-1986 period times the California landings for each year prior to 1977.

Appendix 33. Annual estimates of salmon landed in the ocean recreational fishery. Number of all salmon (1947-1961) and chinook by port area (1962-1986) based on CF&G estimates. Number of CV chinook salmon estimated by applying fractions described below. (Dettman et al., 1987)

Year	All Salmon [1] (number)	Chinook Only (number)	Contribution of CV salmon [2]: CA Total (number)	Oregon (number)	OR + CA (number)
1947	5,018	3,874	2,387	165	2,551
1948	11,209	8,653	5,331	368	5,699
1949	23,057	17,800	10,967	757	11,723
1950	56,337	43,492	26,796	1,849	28,644
1951	71,970	55,561	34,231	2,362	36,593
1952	86,472	66,756	41,129	2,838	43,966
1953	98,723	76,214	46,956	3,240	50,195
1954	119,911	92,571	57,033	3,935	60,968
1955	128,978	99,571	61,346	4,233	65,579
1956	114,505	88,398	54,462	3,758	58,220
1957	44,701	34,509	21,261	1,467	22,728
1958	52,676	40,666	25,054	1,729	26,783
1959	55,945	43,190	26,609	1,836	28,445
1960	37,941	29,290	18,046	1,245	19,291
1961	42,965	33,169	20,435	1,410	21,845

	California Landings of Chinook by Port Area [1]						Landings of Central Valley Chinook by Port Area [2]							
Year	Monterey	San Fran	Ft Bragg	Eureka	C. City	Total	Monterey	San Fran	Ft Bragg	Eureka	C. City	CA Total	Oregon	OR + CA
1962	19,953	77,711	5,988	15,376	527	119,555	18,955	49,308	2,712	6,378	204	77,557	5,351	82,908
1963	6,397	66,177	1,901	8,006	1,289	83,770	6,077	41,989	861	3,321	498	52,747	3,640	56,386
1964	11,014	74,155	8,616	6,865	643	101,293	10,463	47,051	3,902	2,848	249	64,513	4,451	68,964
1965	5,496	45,713	3,069	5,455	483	60,216	5,221	29,005	1,390	2,263	187	38,065	2,627	40,692
1966	2,715	64,362	3,476	2,813	210	73,576	2,579	40,838	1,574	1,167	81	46,239	3,191	49,430
1967	7,650	58,503	2,578	3,165	670	72,566	7,268	37,120	1,168	1,313	259	47,127	3,252	50,379
1968	25,095	123,807	2,623	2,315	404	154,244	23,840	78,556	1,188	960	156	104,700	7,224	111,924
1969	14,737	113,517	3,960	20,638	2,916	155,768	14,000	72,027	1,793	8,561	1,127	97,508	6,728	104,236
1970	13,838	97,300	3,291	32,524	847	147,800	13,146	61,737	1,490	13,491	327	90,192	6,223	96,415
1971	20,448	145,879	2,373	18,051	1,520	188,271	19,426	92,560	1,075	7,488	587	121,136	8,358	129,494
1972	11,089	176,503	4,874	6,882	1,174	200,522	10,535	111,991	2,207	2,855	454	128,042	8,835	136,876
1973	13,886	167,017	5,299	7,584	4,167	197,953	13,192	105,972	2,400	3,146	1,611	126,320	8,716	135,036
1974	11,348	130,242	4,268	9,099	2,508	157,465	10,781	82,639	1,933	3,774	969	100,096	6,907	107,002
1975	7,717	84,977	1,824	7,821	1,395	103,734	7,331	53,918	826	3,244	539	65,858	4,544	70,403
1976	4,800	63,800	2,300	7,100	3,000	81,000	4,560	40,481	1,042	2,945	1,160	50,187	3,463	53,650

Appendix 33. (continued). Annual estimates of salmon landed in the ocean recreational fishery. Number of all salmon (1947-1961) and chinook by port area (1962-1986) based on CF&G estimates. Number of CV chinook salmon estimated by applying fractions described below.(Dettman et al., 1987)

	California Landings of Chinook by Port Area						Landings of Central Valley Chinook by Port Area							
	Monterey	San Fran	Ft Bragg	Eureka	C. City	Total	Monterey	San Fran	Ft Bragg	Eureka	C. City	CA Total	Oregon	OR + CA
1977	4,000	72,600	6,300	13,300	7,400	103,600	3,800	60,839	1,932	7,045	1,591	75,207	10,113	85,320
1978	1,200	64,100	2,400	2,300	2,000	72,000	1,140	45,511	1,605	0	1,358	49,614	1,234	50,848
1979	5,900	102,500	5,800	3,600	4,400	122,200	5,605	61,279	1,324	0	0	68,208	274	68,482
1980	3,100	73,100	1,200	4,000	2,700	84,100	2,945	30,124	456	290	332	34,147	891	35,038
1981	3,100	69,400	1,400	4,400	4,000	82,300	2,945	35,956	546	3,169	2,131	44,747	3,989	48,736
1982	3,900	124,400	2,800	7,100	6,200	144,400	3,705	87,407	3,148	3,889	4,907	103,056	9,351	112,407
1983	2,200	50,000	1,700	5,800	3,400	63,100	2,090	31,725	770	2,406	1,314	38,305	2,643	40,948
1984	5,400	74,100	1,000	4,600	3,500	88,600	5,130	47,016	453	1,908	1,353	55,860	3,854	59,715
1985	7,400	104,100	5,400	26,000	17,800	160,700	7,030	66,051	2,446	10,785	6,880	93,192	6,430	99,622
1986	24,300	86,900	8,000	9,000	5,400	133,600	23,085	55,138	3,623	3,733	2,087	87,667	6,049	93,716
Averages														
1957-1976						98,979						60,077	4,343	67,280
1977-1986						95,873						59,091	4,075	63,166

1 Sources: Years 1947-1961, Young (1969); 1962-1965, Jensen and Swartzell (1967); 1966-1975, CF&G Fish Bulletin Nos. 133, 144, 149, 153, 154, 161, 163, 166, 168; 1976-1980, PFMC (1986); 1981-1986, PFMC (1987).

2 Annual contributions of CV chinook based on the recovery of coded wire tagged salmon in the recreational fishery off California and Oregon (see Table A-7). Contributions to California and Oregon ports for the 1977-1982 period were estimated by dividing the estimated number of CWT recoveries by an estimate of the fraction of CV fish with tags. Contributions to California ports during the 1962-1976 and 1983-1986 periods, and contributions to Oregon ports during the 1983-1986 period were estimated by multiplying the number of fish landed times the overall fraction of fish in the fishery that were estimated to be from CV during the 1977-1982 period (see Table A-7). Contributions to California ports during the 1947-1961 period were estimated by: 1) multiplying total salmon landings times the fraction of salmon that were chinook in the 1962-1967 period and then multiplying the number of chinook times the overall fraction of salmon that were from CV during the 1977-1982 period. Oregon landings prior to 1977 were estimated by multiplying the ratio of Oregon landings of CV fish divided by California landings of CV fish from the 1977-1982 period times the California landings of CV fish prior to 1977.

SUMMARY OF QUALIFICATIONS

Name: Patricia Little Brandes

Address: U.S. Fish and Wildlife Service
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Position: Fisheries Biologist, Stockton
Fisheries Assistance Office

Education: B.S. Fisheries
Michigan State University, Lansing, MI - 1982

Employment: U.S. Fish and Wildlife Service, 1981 to Present

Jordan River National Fish Hatchery, Elmira, MI
Fisheries Biologist Trainee - March, 1981 - Dec. 1981

Senecaville National Fish Hatchery, Senecaville, Ohio
Fisheries Biologist - April, 1982 - May, 1983

Stockton Fisheries Assistance Office, Stockton, CA
Fisheries Biologist - August, 1983 to Present.

Responsibilities:

Responsible for conducting field programs and analyzing data on the abundance and survival of juvenile chinook salmon in the Sacramento-San Joaquin Delta.

Professional Organizations:

Member of the American Fisheries Society, Sports Fishing Institute, Pacific Fishery Biologists, San Francisco Bay and Estuarine Society.

USFWS Exhibit No. 32

SUMMARY OF QUALIFICATIONS

NAME: JOHN D. MCINTYRE

ADDRESS: NATIONAL FISHERY RESEARCH CENTER, BLDG. 204, NAVAL STATION, SEATTLE, WA 98115

POSITION: SECTION LEADER, POPULATION ECOLOGY RESEARCH

EDUCATION: PHD, OREGON STATE UNIVERSITY 1969, FISHERY BIOLOGY

EMPLOYMENT:

1969-70 FACULTY, DEPARTMENT OF FISHERIES AND WILDLIFE, OREGON STATE UNIVERSITY, CORVALLIS, OREGON.

1970-73 ASSISTANT LEADER, OREGON COOPERATIVE FISHERY RESEARCH UNIT, DEPARTMENT OF FISHERIES AND WILDLIFE, OREGON STATE UNIVERSITY, CORVALLIS, OREGON.

1973-77 LEADER, OREGON COOPERATIVE FISHERY RESEARCH UNIT, DEPARTMENT OF FISHERIES AND WILDLIFE, OREGON STATE UNIVERSITY, CORVALLIS, OREGON.

1977-78 PROJECT LEADER, NATIONAL FISHERY RESEARCH CENTER, SEATTLE, WA

1978-79 PROJECT LEADER, FISHERIES ASSISTANCE OFFICE, RED BLUFF, CALIFORNIA.

1979-PRESENT SECTION LEADER, POPULATION ECOLOGY RESEARCH, NATIONAL FISHERY RESEARCH CENTER, SEATTLE, WA

RESPONSIBILTIES:

PROVIDE THE TECHNICAL LEADERSHIP FOR THE CENTER'S RESEARCH IN FISH POPULATION BIOLOGY IN THE WESTERN STATES AND CONDUCT PERSONAL RESEARCH IN FISH BIOLOGY

WORK EXPERIENCE:

EXPERIENCE HAS INCLUDED RESEARCH IN ALL ASPECTS OF POPULATION BIOLOGY (GENETICS, POPULATION DYNAMICS, AND ECOLOGY) WITH PACIFIC ANADROMOUS SALMONIDS THROUGHOUT THEIR RANGES ALONG THE PACIFIC COAST. MANAGEMENT EXPERIENCE GAINED AS PROJECT LEADER FOR THE FISH AND WILDLIFE SERVICE'S FISHERY ASSISTANCE PROGRAM IN CALIFORNIA (CENTRAL VALLEY AND KLAMATH RIVER).

USFWS EXHIBIT NO. 33

SUMMARY OF QUALIFICATIONS

Name: Dr. Reginald R. Reisenbichler

Address: National Fishery Research Center
U.S. Fish and Wildlife Service
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Position: Fishery research biologist in population ecology

Education:
- B.S. in Zoology (minor in mathematics) from Oregon State University (1972).
- M.S. in Fishery Biology (minor in statistics) from Oregon State University (1976).
- Ph.D. in Fishery Biology (population dynamics and statistics) from University of Washington (1986).

Employment:
- 1974-76, Oregon State University, graduate research assistant in fisheries, Corvallis, Oregon.
- 1976-77, Oregon Department of Fish and Wildlife, fishery research biologist, Corvallis, Oregon.
- 1977-80, U.S. Fish and Wildlife Service, fishery biologist, Lander, Wyoming, and Red Bluff, California.
- 1980-present, U.S. Fish and Wildlife Service, fishery research biologist, Seattle, Washington.

Responsibilities:
Design and conduct research in the population ecology of anadromous salmonids and endangered species.

Work experience:
Research in statistics and experimental design, and in population genetics, population dynamics, stream ecology, and life histories of anadromous Pacific salmonids from California to Alaska (see list of publication and reports for more detail.)
Management of resident fish species in Wyoming and of anadromous Pacific salmonids in the Central Valley of California.

USFWS EXHIBIT NO. 34